Marine Fisheries REVIEW

Vol. 46, No. 3
1984

National Oceanic and Atmospheric Administration • National Marine Fisheries Service

Satellites and Fisheries

Marine Fisheries REVIEW

On the cover: Sea surface temperature image from an infrared sensor on NOAA-7 satellite, 25 May 1982. Warmer waters and land appear dark, colder water and clouds are lighter. Note the plume of warm surface water from the Columbia River and the jets of cold upwelled water to the south.

Articles — *46(3), 1984*

Fisheries Applications of Satellite Data in the Eastern North Pacific	*Paul C. Fiedler, Gary B. Smith* and *R. Michael Laurs*	1
Marine Bivalve Mollusks as Reservoirs of Viral Finfish Pathogens: Significance to Marine and Anadromous Finfish Aquaculture	*Theodore R. Meyers*	14
The "Tuna-Porpoise" Problem: NMFS Dolphin Mortality Reduction Research, 1970-81	*James M. Coe, David B. Holts,* and *Richard W. Butler*	18
History of Artificial Propagation of Coho Salmon, *Oncorhynchus kisutch,* in the Mid-Columbia River System	*Roy J. Wahle* and *Roger E. Pearson*	34
Norwegian Salmon and Trout Farming	*Robert J. Ford*	44
Using Charterboat Catch Records for Fisheries Management	*Harold A. Brusher, Mark L. Williams, Lee Trent,* and *Barbara J. Palko*	48
The Incidental Capture of Sea Turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese Tuna Longline Fleet, 1978-81	*W. N. Witzell*	56
Encounters of Hawaiian Monk Seals With Fishing Gear at Lisianski Island, 1982	*John R. Henderson*	59
Paired Open Beach Seines to Study Estuarine Migrations of Juvenile Salmon	*Herbert W. Jaenicke, Adrian G. Celewycz, Jack E. Bailey,* and *Joseph A. Orsi*	62
Nonselectivity of Gillnet Fishery on Jaw-Tagged Adult Steelhead, *Salmo gairdneri*	*Emil Slatick* and *Larry Basham*	68
Proximate Composition of Certain Red Sea Fishes	*Rifaat G. M. Hanna*	71
Assessing the Accuracy of a Method to Determine the Amount of Minced Fish in Mixed Mince-Fillet Fish Blocks	*J. Perry Lane, John J. Ryan,* and *Robert J. Learson*	76

Departments

NOAA/NMFS Developments	80
Foreign Fishery Developments	86
Publications	96

U.S. DEPARTMENT OF COMMERCE

Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

John V. Byrne, Administrator
William G. Gordon, Assistant Administrator for Fisheries

National Marine Fisheries Service

Editor: W. Hobart

Marine Fisheries Review (USPS 090-080) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700 Seattle, WA 98115.

Single Copies and annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Prices are: Single copy, $4.00 domestic, $5.00 foreign; annual subscription, $8.75 domestic, $10.95 foreign. Copies of individual articles, in limited numbers, are available from the Publications Services Branch (E/A113), National Environmental Satellite, Data, and Information Service, NOAA, Washington, DC 20235. News items are not reprinted.

Publication of material from sources outside the NMFS is not an endorsement and the NMFS is not responsible for the accuracy of facts, views, or opinions of these sources. The Secretary of Commerce has determined that the publication of this periodical is necessary for the transaction of public business required by law of this Department. Use of the funds for printing this periodical has been approved by the Director of the Office of Management and Budget.

The NMFS does not approve, recommend or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication.

Second class postage paid at Finance Department, USPS, Washington, DC 20260.

Fisheries Applications of Satellite Data in the Eastern North Pacific

PAUL C. FIEDLER, GARY B. SMITH, and R. MICHAEL LAURS

ABSTRACT—Satellite sensors provide extensive and detailed images of sea surface temperature and color. Synoptic daily sampling by satellites gives a unique view of the ocean surface that can be extremely useful when used in conjunction with conventional shipboard data. Current and potential applications of satellite data off the U.S. Pacific coast and Alaska include interpretation of ship survey data, explanation of pelagic fisheries distributions, prediction of stock recruitment, spatial/temporal monitoring of the coastal zone and sea ice, studies of migration routes and timing, and production of charts to aid commercial fisheries.

Introduction

Remote sensing of the ocean is playing an increasingly important role in fishery research and fish harvesting along the Pacific coast of the United States and Canada. Satellite sensors make synoptic measurements of water temperature and color, winds, ice cover, wave height, and surface currents over large areas of the ocean surface. Variations in these ocean conditions play key roles in natural fluctuations of fish stocks and in their vulnerability to harvesting.

The promise of remote sensing techniques for fisheries research, management, and exploitation has been recognized since the early 1960's when the first visible and infrared images of the earth's surface were obtained from orbit. However, successful applications have only recently been realized with the advent of advanced and sensitive radiometers, high-speed data processing, and the availability of imagery to fishery scientists and fishermen.

Gower (1982) provides a useful overview of the different kinds of remote sensing data relevant to fisheries science and oceanography. Laurs and Brucks (In press) review living marine resources applications in the United States. Yamanaka (1982) gives examples of some uses of satellite data for fisheries applications off Japan. Other potential, ocean-related uses of remote sensing data were discussed by Montgomery (1981). This paper will review the satellite sensors currently measuring sea surface temperature and ocean color, data processing and availability, and several examples of recent and potential applications to eastern North Pacific fisheries.

Satellites provide a unique view of the ocean by covering large areas synoptically. Coverage of historically data-poor areas is particularly useful. However, satellite measurements are usually limited to the surface or near-surface layers in cloud-free areas. Therefore, satellite data complement conventional shipboard observations but cannot replace them. The best research approach often requires close coordination of the two sources of information. In this way, the evolving capabilities of satellite remote sensing are providing a powerful tool to enhance the efficient use of living marine resources.

Satellite Sensors

A variety of instruments measure radiance from the earth's surface in visible, thermal infrared (IR), and microwave wavelength bands (Table 1). The most readily available and useful data come from the Advanced Very High Resolution Radiometer (AVHRR) on meteorological satellites operated by the National Oceanic and Atmospheric Administration (NOAA) and the Coastal Zone Color Scanner (CZCS) on the experimental Nimbus-7 satellite operated by the National Aeronautics and Space Administration (NASA). These advanced sensors are characterized by high sensitivity in narrow wavelength bands, fine ground resolution, and extensive data archival.

Satellites receive electromagnetic radiation emitted from the sea surface (the IR temperature signal) and back scattered from below the surface (the visible ocean color signal). These signals are contaminated by reflection from the sea surface and clouds, and by absorption, emission, and scatter by atmospheric particulates and molecules. Some of these errors can be eliminated or minimized very simply. For example, sunglint and "limb darkening" (by long atmosphere paths at oblique viewing angles) are avoided by constraining the viewing geometry of the sensor. Corrections of some other errors, however, require advanced image processing methods.

Dense clouds may so completely absorb visible and IR radiation from the sea surface that no type of data

Paul C. Fiedler and R. Michael Laurs are with the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, 8604 La Jolla Shores Drive, La Jolla, CA 92038. Gary B. Smith is with the Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112.

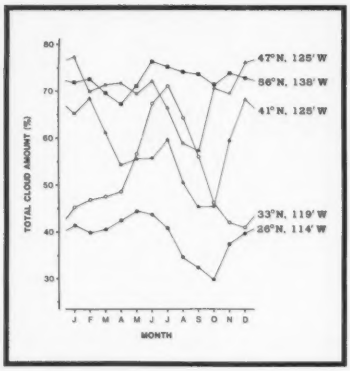


Figure 1.—Mean monthly total cloud amount over coastal waters, from surface marine weather observations, 1921-72 (Nelson and Husby, 1983): Baja California (27°N, 115°W), Southern California Bight (33°N, 119°W), Cape Mendocino (41°N, 125°W), Vancouver Island (48°N, 126°W). Gulf of Alaska data (56°N, 138°W) are from satellite observations, 1967-72 (Sadler et al., 1976), intercalibrated against data from Nelson and Husby (1983).

Table 1.—Some satellite sensors measuring visible, infrared, or microwave radiance for oceanographic measurements. Wavelengths are band midpoints. Ground resolution dimensions are directly beneath the satellite.

Sensor[1]	Satellite	Channel	Spectral band	Wavelength (μm)	Scan width (km)	Ground resolution (km)	Primary measurements
AVHRR	TIROS-N NOAA-6, 7, 8	1	Visible	0.63	3,000	1.1	Sea surface temperature, sea ice
		2	Near-infrared	0.91			
		3	Infrared	3.74			
		4	Infrared	10.8			
		[2]5	Infrared	[2]12.0			
CZCS	Nimbus-7	1	Visible	0.44	1,566	0.825	Phytoplankton pigments, turbidity, sea surface temperature
		2	Visible	0.52			
		3	Visible	0.55			
		4	Visible	0.67			
		5	Near-infrared	0.75			
		6	Infrared	11.5			
MSS	LANDSAT	1	Visible	0.55	185	0.079	Water color, turbidity, sea ice
		2	Visible	0.65			
		3	Near-infrared	0.75			
		4	Near-infrared	0.95			
VISSR	GOES	1	Visible	0.62	Earth disk	7×3	Cloud cover, sea surface temperature
		2	Infrared	11.5			
SMMR	Nimbus-7 SEASAT	1	Microwave	4.54×10^4	600	20-100	Sea surface temperature, sea ice, near-surface winds
		2	Microwave	2.8×10^4			
		3	Microwave	1.66×10^4			
		4	Microwave	1.36×10^4			
		5	Microwave	0.81×10^4			

[1]Sensors: AVHRR = Advanced Very High Resolution Radiometer; CZCS = Coastal Zone Color Scanner; MSS = Multispectral Scanner; VISSR = Visible and Infrared Spin Scan Radiometer; SMMR = Scanning Multichannel Microwave Radiometer.
[2]Channel 5 on NOAA-7 and NOAA-8 satellites only.

processing can retrieve a useful signal. Clouds severely limit satellite coverage of the sea surface in some regions of the eastern North Pacific, particularly north of lat. 40°N (Fig. 1). South of lat. 27°N, off Baja California, mean monthly cloud cover is consistently less than 50 percent, due to persistent offshore flow of dry continental air. From lat. 30°N to 38°N, coastal waters are covered by a dense layer of low stratus clouds during the summer upwelling season (Nelson and Husby, 1983). The most favorable conditions for remote sensing at these latitudes are found from October through March or April, especially during occasional brief periods when Santa Ana winds blow warm, dry desert air offshore and produce cloud-free conditions up to 1,000 km from the coast.

In contrast, the most cloud-free conditions at lat. 40°–50°N are found in late summer, from August to October. Mean monthly cloud cover increases to the north and is consistently 70 percent or greater in the Gulf of Alaska, although March and April may be relatively clear. As a general rule, percent cloud cover increases by at least 10 percent from the coast to a distance on the order of 200 km offshore in the eastern North Pacific (Nelson and Husby, 1983).

The probability of cloud-free conditions in a region of interest during regular satellite passes is loosely reflected in these monthly cloud cover statistics. Cloud cover restricts the extent to which satellite data can be anticipated, or depended upon, to be available. Whereas it may be possible to obtain regular daily or weekly coverage of sea surface features in the south, such as in the Southern California Bight, in the north there are generally more frequent and longer data gaps. Satellite coverage of ocean features in the Alaska region is characteristically limited to occasional cloud-free scenes that, despite being infrequent, can be rich in information. Microwave radiometers can measure sea surface temperature through clouds, but with a lower sensitivity and much coarser resolution than IR radiometers.

Data Processing

The AVHRR measures thermal infrared radiant energy in three wavelength bands (Table 1). Temperature calibration data are obtained by scanning deep space and internal blackbody targets. Accurate sea surface temperatures are calculated from empirical regressions of ship and buoy temperatures on satellite temperatures in two or three bands. Such multispectral corrections are based on the different response of each band to the cold bias caused by atmospheric water vapor (McClain et al., 1983). Pixels (samples) containing clouds even smaller than the sensor's field of view are screened in daytime passes using the near-infrared albedo data from channel 2 (Bernstein, 1982).

The CZCS measures visible light in five narrow wavelength bands

selected for estimating phytoplankton pigments, suspended sediments, and dissolved organic matter. Up to 90 percent of the visible radiance received at the satellite is skylight reflected and scattered within the atmosphere. Corrections are based on assumptions that the red light emitted by the ocean and measured by channel 4 is either negligible or can be accurately predicted from radiances in other bands. The atmospheric radiance measured by channel 4 can then be related to atmospheric radiances in other channels using known spectral properties of atmospheric scattering (Gordon et al., 1983). Corrected ratios of blue to yellow-green (channel 1/channel 3) or green to yellow-green (channel 2/channel 3) radiance are then used to calculate phytoplankton pigment concentration from empirical regression relationships (Smith and Baker, 1982).

Satellite data, properly corrected for the various errors described above, have been validated by sea truth data from ships to $\pm$ <1°C (Bernstein, 1982) and $\pm$0.4 log chlorophyll concentration (Smith and Baker, 1982). While important subsurface features such as chlorophyll maximum layers and some cold-core eddies or oceanic fronts may not be detected by satellites, the measured parameters are, in general, closely related to properties such as mixed-layer temperature and integrated chlorophyll or primary productivity in the euphotic zone (Smith, 1981).

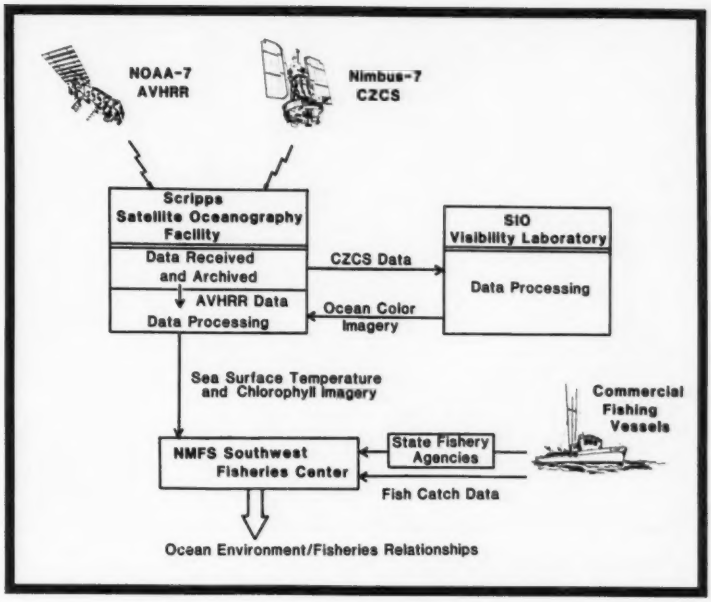


Figure 2.—Satellite data collection and processing network utilized by the National Marine Fisheries Service on the west coast.

Data Availability

Applications of satellite data are ultimately limited by their availability. Ideally, a user would have immediate access to data received directly from satellites and conveniently archived, with data processing facilities at his fingertips. This ideal has been approached by an arrangement at the Satellite Oceanography Facility of Scripps Institution of Oceanography in La Jolla, Calif., for most of the work reported here (Fig. 2). Similar arrangements, lacking direct data reception capabilities, have been established at the University of Miami and by the Northeast Area Remote Sensing System, which is a regional association of university, industry, and government organizations that was recently formed in the northeastern United States.

Global satellite data are archived by the Satellite Data Services Division of NOAA and are available to the public, although acquisition may require several months and a large backlog of CZCS data is unprocessed. AVHRR and CZCS data are available in various forms including photographic prints and negatives, digital data on magnetic tapes, and maps of derived sea surface temperature and ice cover. These products and a catalog of available CZCS data are available from the National Environmental Satellite Data and Information Service, Satellite Data Services Division, NOAA, Room 100, World Weather Building, Washington, DC 20233. Detailed procedures for obtaining environmental satellite data are given in Cornillon[1]. In general, photographic copies of raw data are of limited value and a user must have access to a computer-based, image processing system to extract useful information from satellite data on digital tapes (this situation may change in the future if products derived from satellite data are offered by commercial processing enterprises).

Applications

We briefly review here examples of general applications of satellite data to fisheries research and management problems along the Pacific coast between California and Alaska. Some of these examples have been published elsewhere, but none of the applications has as yet been fully realized.

[1]Cornillon, P. 1982. A guide to environmental satellite data. Univ. R. I. Mar. Tech. Rep. 79, 469 p. Available for $20.00 from the University of Rhode Island, Marine Advisory Service, Publication Unit, Narragansett, RI 02882.

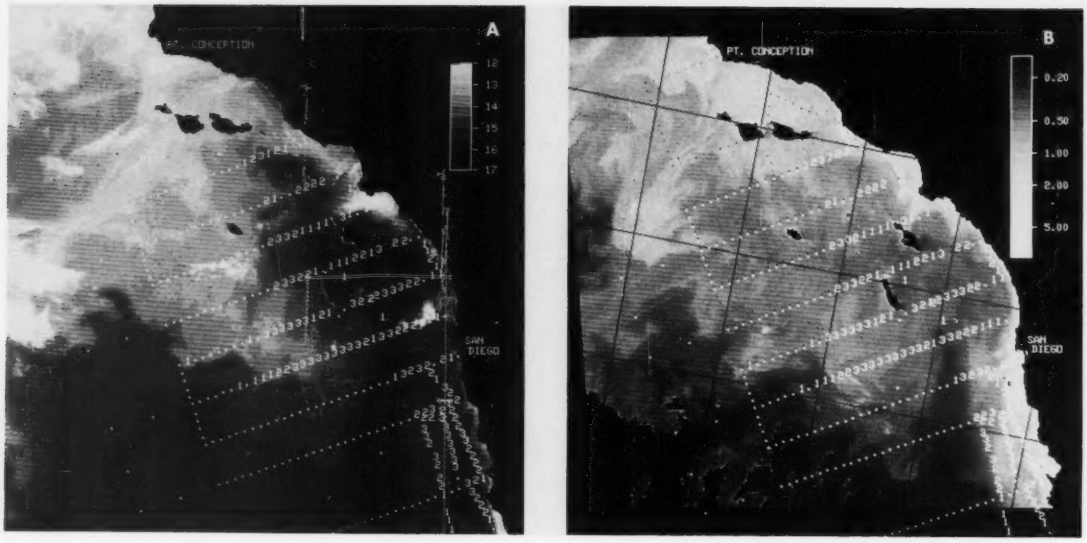


Figure 3.—Northern anchovy egg distribution, 20 March-10 April 1980; • = 0, 1 = 1-4, 2 = 5-17, 3 = 18-245 eggs/0.05 m^2. Top photo (A) is sea surface temperature (°C) from NOAA-6 AVHRR, 7 April 1980; Photo B is of phytoplankton pigments (mg m^{-3}) from Nimbus-7 CZCS, 8 April 1980.

Interpretation of Ship Survey Data

A large stock of northern anchovy, *Engraulis mordax,* is found off southern California, where intensive egg surveys have been conducted since 1980 to estimate spawning biomass. Satellite images of sea surface temperature and phytoplankton pigment concentration, obtained during an egg survey in April 1980, depict environmental limits on the range of spawning anchovy (Fig. 3). North of San Diego, no eggs were found in water colder than 14°C. To the south, spawning northern anchovy were confined along the coast to a narrow band of water with high pigment concentrations. Similar distribution patterns were observed in 1981 and 1982 (Lasker et al., 1981; Fiedler, 1983).

The distribution of spawning adults may reflect the critical need by first-feeding larvae for aggregations of suitable food organisms in a stable water column. The environmental limits revealed by the satellite images would not have been revealed by the egg survey data alone, because phytoplankton pigments were not measured and spatial coverage was limited.

Satellites data may be used to interpret the large-scale patterns and possible causes of spatial/temporal variability in other types of ship survey data. Most measurements of fish eggs and larvae, plankton concentrations, chlorophyll, nutrients, temperature, and salinity are made at point locations at regular intervals along transects or in grid patterns. Remote sensing data collected concurrently, if available, may provide valuable information on factors contributing to patterns in the shipboard data and on conditions beyond the area surveyed. Besides the insight that usually results from a synoptic view, this information is important in evaluating the validity of interpolation and extrapolation of ship survey results.

Pelagic Fisheries Distribution

Albacore, *Thunnus alalunga*, is a migratory oceanic tuna that is an important target species for jigfishing, live bait, and recreational fishing along the U.S. Pacific coast from July to October. Fishermen search for aggregations of these fish in warm, blue oceanic waters near temperature or water color fronts at the offshore edge of productive coastal waters. Daily catch records during peak fishing in late summer 1981 were taken from logbooks submitted to west coast state fisheries agencies. Concentrations of fishing activity and large catches indicate sites of albacore aggregations.

Satellite images of sea surface temperature and phytoplankton pigment concentrations clearly show favorable sites for aggregations in pockets of warm, blue oceanic water intruding into the colder and more turbid coastal water mass (Fig. 4; Laurs et al., In press). Albacore are visual predators and may feed most efficiently in the clear water adjacent to coastal waters where prey densities are higher. Albacore fishermen, running several days out of port in small boats to reach offshore fishing grounds, can benefit from timely maps of sea surface temperature and ocean color gradients derived from satellite data. Potential benefits include decreased search time, lower fuel use, and increased catches.

Satellite data may be applied to

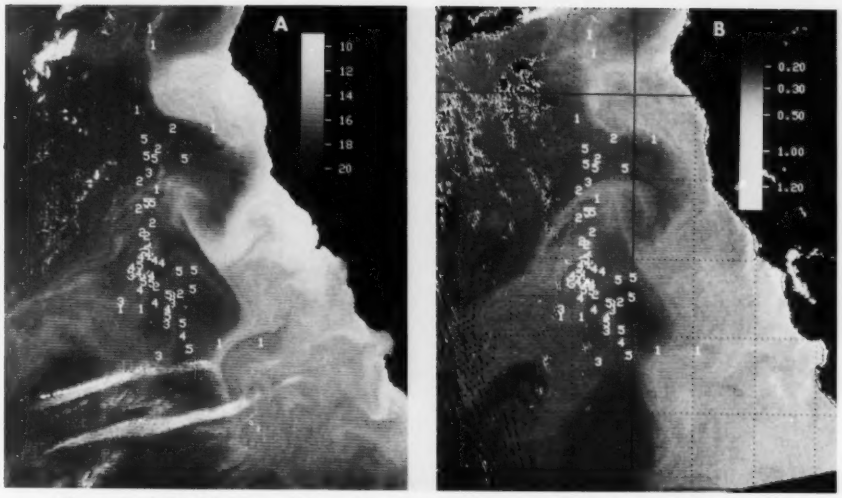


Figure 4.—Daily albacore catches off central California, 19-24 September 1981: 1 = 0-27, 2 = 33-63, 3 = 64-81, 4 = 87-140, 5 = 148-750 fish/boat. A is sea surface temperature (°C) from NOAA-7 AVHRR, 21 September 1981; B is phytoplankton pigments (mg m^{-3}) from Nimbus-7 CZCS, 22 September 1981.

other pelagic fisheries, both to direct fishing effort and for fisheries management. In the Pacific Northwest and off Alaska, five species of Pacific salmon—sockeye salmon, *Oncorhynchus nerka*; chum salmon, *O. keta;* pink salmon, *O. gorbuscha*; chinook salmon, *O. tshawytscha*; and coho salmon, *O. kisutch*—are important resources for a large fishing industry. During their oceanic life history phase, these salmon are caught by power or hand-trolling boats using methods similar to albacore fishing. The study described by Borstad et al. (1982) is an example of a use of remote sensing techniques to study relationships between salmon distributions, fishing, and oceanographic conditions. Other pelagic resources for which there may be analogous applications include Pacific herring, *Clupea harengus pallasi,* off Alaska; jack mackerel, *Trachurus symmetricus,* and Pacific mackerel, *Scomber japonicus,* off California; and bluefin tuna, *Thunnus thynnus orientalis,* off Baja California.

Stock Recruitment Predictions

An application of satellite data that merits investigation is the improved understanding and prediction of variations in recruitment to coastal fish stocks. In the eastern North Pacific, offshore transport and turbulent mixing may have important effects on the larval survival and subsequent recruitment of some species (Bakun and Parrish, 1982). Both processes are driven by surface wind stress. Offshore transport removes eggs and larvae from productive nearshore nursery grounds. This may be most important where strong seasonal upwelling occurs over a narrow continental shelf, as it does along the U.S. coast north of lat. 34°N. Turbulent mixing reduces stratification of the near-surface water column and disrupts aggregations of food organisms required for successful first feeding by newly hatched larvae (Lasker, 1981).

Variations in annual recruitment of Pacific whiting, *Merluccius productus,* have been related to monthly mean Ekman transport estimated from equatorward wind stress off central California (Bailey, 1981). Fiedler (1984) has used AVHRR imagery to document interannual changes in the sea surface temperature field related to variations in coastal upwelling off the U.S. Pacific coast. Satellite imagery has also revealed that offshore transport is a highly irregular process in both time and space, manifested as meandering jets and eddies of cold water (e.g. Fig. 5). Offshore transport could perhaps be quantified by measuring the areal extent of relatively cold water nearshore or the offshore displacement of frontal features between daily satellite passes. This application may be extended to other species for which there is evidence of similar environmental effects (e.g. Hayman and Tyler, 1980; Bakun and Parrish, 1982).

The seasonal timing and spatial location of northern anchovy spawning has been related to turbulent mixing, as indexed by the cube of mean surface wind speed in historical marine weather observations, by Husby and Nelson (1982). They suggested that strong year classes may depend upon the occurrence of "time-space windows" with sufficiently low turbulence to allow development of layers of food organisms.

The magnitude and direction of surface wind stress are directly

Figure 5.—Localized offshore transport of cold upwelled water (whiter shades) off northern California and southern Oregon. The three major coastal landforms, from top to bottom, are Cape Blanco, Cape Mendocino, and Point Arena. White features in the top left corner are clouds. Image from NOAA-7 AVHRR channel 4, 14 June 1982.

measurable by microwave sensors such as the scatterometer which flew on the short-lived SEASAT satellite in 1978. The U.S. government has not yet committed funds to orbit another such sensor, for which there are many potential scientific and commercial applications (NASA Satellite Wind Stress Working Group, 1982). Fisheries applications might include the real-time planning of fishing operations to avoid adverse sea state conditions, as well as the measurement of surface winds driving environmental processes affecting recruitment into coastal fish stocks. These benefits would be particularly significant in northern areas, such as the Pacific Northwest and Alaska regions, where present remote sensing coverage by visible and infrared sensors is usually limited by cloud cover.

Coastal Zone Monitoring

Mesoscale processes, such as upwelling and eddy formation, are very important components of the spatial and temporal variability of eastern North Pacific coastal waters, especially in the complex California Current System. Extensive and high-resolution satellite data are particularly valuable for studies of these processes (Bernstein et al., 1977). Anomalous ocean conditions along the U.S. Pacific coast were monitored during the 1982-83 El Niño event using AVHRR and CZCS data (Fiedler, 1984). Localized sea surface temperature anomalies up to +6°C were observed. Reduced coastal upwelling during the first half of the year was detected in patterns of cold, nearshore surface waters. CZCS images of the Southern California Bight indicated reduced phytoplankton productivity. This event affected many commercial and sport fisheries along the coast (Anonymous, 1984).

Monitoring coastal zone variability within a year or season with satellite data may be useful for developing better release strategies for hatchery-reared juvenile salmonids by enabling management decisions to be more adaptive and based on conditions in nearshore nursery areas. It might be possible to improve the growth and survival of hatchery-reared salmon by scheduling releases during periods of most favorable ocean conditions. AVHRR and CZCS imagery could be used as sources of information on sea surface temperature, river plume trajectory, upwelling intensity, primary production, and the oceanic frontal areas associated with each of these factors. Small improvements in the survival of juveniles released from hatcheries could result in substantial increases in the numbers of returning adults. If successful, this application would be particularly important in the Pacific Northwest and Alaska region, where hatchery operations are extensive and salmon resources have high value.

Salmon enhancement programs on the Columbia River, the largest river on the Pacific Coast of North America, provide an example of the potential. The National Marine Fisheries Service funds 22 salmon hatcheries and 7 rearing ponds on the Columbia River at an annual cost exceeding $4.5 million. Each year, these facilities culture and release 80-100 million salmon smolts in late April and early May. The present release schedule is decided largely on the basis of administrative criteria, tradition, and attempts to emulate nature. However, survival rates for these hatchery-reared salmon are relatively low, only about 3.7 percent (range, 0.23 to 12.35 percent) for coho salmon in their first year (Mathews, 1980).

There is increasing evidence that juvenile salmon survival, and subsequent adult returns, are critically influenced by conditions in the ocean environment within the first 6 months after hatchery release (Hartt, 1980; Wahle and Zaugg, 1982). Important factors may be food availability and the extent that food limitations occur in the nursery habitats as a result of crowding. On the Columbia River, although hatchery-reared salmon pass downstream and through the lower river and estuary relatively rapidly, significant losses occur in each of these migratory stages and areas. After reaching the ocean, juvenile salmon typically migrate along a relatively narrow coastal belt (Hartt, 1980). In purse seine studies off the Columbia River, juvenile salmonids (< 50 cm) have been found to be distributed mainly within 28 km of shore; chinook salmon and steelhead, *Salmo gairdneri,* were distributed almost entirely in the river plume (Miller et al., 1983). Upwelling and its effects on food production have been related to juvenile survival and adult salmon production (Gunsolus[2]). A better understanding of these environmental relationships is a goal of current research.

Figure 6 shows three satellite images of sea surface temperatures along

[2]Gunsolus, R. T. 1978. The status of Oregon coho and recommendations for managing the production, harvest, and escapement of wild and hatchery-reared stocks. Oreg. Dep. Fish Wildl., Columbia Reg. Off., 17330 S.E. Evelyn St., Clackamas, OR 97015. Unpubl. manuscr., 59 p.

the Pacific Northwest coast during summer 1982, illustrating changes in coastal conditions that can occur over relatively short (2-3 week) time intervals. On 5 July, coastal upwelling was very weak, although signs of intensification were developing at Cape Mendocino. By 23 July, upwelling had intensified considerably, especially to the north. By 18 August, however, upwelling was again weaker. Changes in the mesoscale pattern of cold-water jets and meanders can be seen. In the latter two images, the Columbia River plume is indicated by a dark, warm-water break in the band of cold, upwelled water along the coast.

Figure 6.—Variations in the intensity and pattern of coastal upwelling off the Pacific Northwest between lat. 39°00'N and 48°30'N, July-August 1982. Sea surface temperature (°C) from NOAA-7 AVHRR channels 4 and 5. Clouds (white) screened with channel 2 data.

Monitoring Sea Ice

Sea ice is an important seasonal feature of the Alaskan environment that can be monitored by satellite coverage (Weeks, 1981; McNutt, 1981). Ice affects commercial fishing activities by threatening vessel safety, limiting navigation and access, and damaging fishing gear. Yet sometimes waters near the edge of pack ice can offer shelter or rich fishing grounds. Ice is also important because of its significance in the ecology of, and as a habitat for, northern marine mammals.

In the eastern North Pacific, winter ice cover occurs in inlets along the coasts of southeastern Alaska, the Gulf of Alaska, and the Aleutian Islands. Its formation is often associated with freshwater runoff, such as in Cook Inlet (Poole and Hufford, 1982). Freshwater ice forms on stream and river deltas, then sea ice forms in lower parts of the embayments. However, much greater ice cover occurs in the extended area to the north. Ice covers the Chukchi Sea, Bering Strait, and nearly the entire northeast half of the eastern Bering Sea during winter and spring. Movements of pack ice in the Bering Sea are influenced by winds and water currents, and are highly dynamic.

Ice off the North Slope, along the southern coast of Alaska, and in the Bering Sea, is monitored routinely by the National Weather Service. When cloud cover permits, ice and open water can be discriminated with a 1 km resolution using AVHRR visible and infrared data (Fig. 7). Combined with data from the Nimbus-7 Scanning Multichannel Microwave Radiometer, which are not influenced by clouds but have a resolution of 60 km, large-scale maps of ice coverage or concentration are produced. Some information about ice type (age and thickness) can be gleaned from satellite data, but the analysis is supplemented by aerial reconnaissance and reports from ships and shore stations. Ice analysis maps are distributed to users in the fishing and oil industries three times a week by radio facsimile and once a week by mail.

Winter fisheries affected by ice cover in the eastern Bering Sea include: Foreign groundfish fisheries, involving 200-300 vessels per year and an annual catch of about 1.3 million metric tons (Bakkala et al., 1979); highly-valued U.S. fisheries for king crab, *Paralithodes* spp., and snow (Tanner) crab, *Chionoecetes* spp. (Otto, 1981); and U.S. fisheries for Pacific herring that take place along the north shore of Bristol Bay. Vessels operating in these fisheries often need to work around sea ice, can have stability problems, and are sometimes trapped in shifting pack ice and lost.

Ice is an important part of the habitat of 25 species of marine mammals that occur in the Bering Sea (Fay, 1974; Burns et al., 1981). It may serve as a substrate, barrier, or to force migrations. Species that regularly come in contact with ice include the following: Polar bear, *Ursus maritimus;* walrus, *Odobenus rosmarus;* harbor seal, *Phoca vitulina;* ringed seal, *P. hispida;* ribbon seal, *P. fasciata;* bearded seal, *Erignathus barbatus;* narwhal, *Monodon monoceros;* beluga whale, *Delphinapterus leucas;* and bowhead whale, *Balaena mysticetus.* For these and other species, the wide views of ice

Figure 7. – Ice cover in the eastern Bering Sea, 18 February 1983, NOAA-7 AVHRR channel 4. Ice, clouds, and snow-covered land all appear whiter (colder) than open water. Pack ice extends from the Bering Strait, in the top left corner, past St. Matthew and Nunivak Islands, but does not reach the Alaska Peninsula to the southeast. Photograph courtesy of G. L. Hufford, NOAA/NESDIS, Satellite Field Services Station, Anchorage, Alaska.

characteristics that can be obtained from satellite imagery provide unique information for use in conservation and management.

Migration Routes and Timing

Satellite imagery can provide useful information on environmental conditions related to the routes and timing of long-distance migrations by marine mammals and fish. In the eastern North Pacific and in waters off Alaska, many important species occupy large habitat areas and make extensive seasonal migrations. These large activity areas are often in remote and data-poor regions. Satellite coverage, because of its wide areal views and long-term repeated observations, provides data with time and space characteristics that are appropriate for interpreting large-scale migratory phenomena. Applications include planning research, experimental design, and evaluating strategies for population enumeration.

The North Pacific albacore, *Thunnus alalunga,* performs transpacific migrations and supports important commercial fisheries in the western, central, and eastern North Pacific. Seasonal migration into North American coastal waters is associated with the Transition Zone between Pacific central and subarctic water masses (Laurs and Lynn, 1977). The frontal structure of these waters may affect both the timing and location of the arrival of albacore into the summer fishery along the coast. Figure 8 illustrates CZCS color frontal patterns in the central Pacific that could influence the course of the migration.

The potential for using both color and infrared temperature imagery in

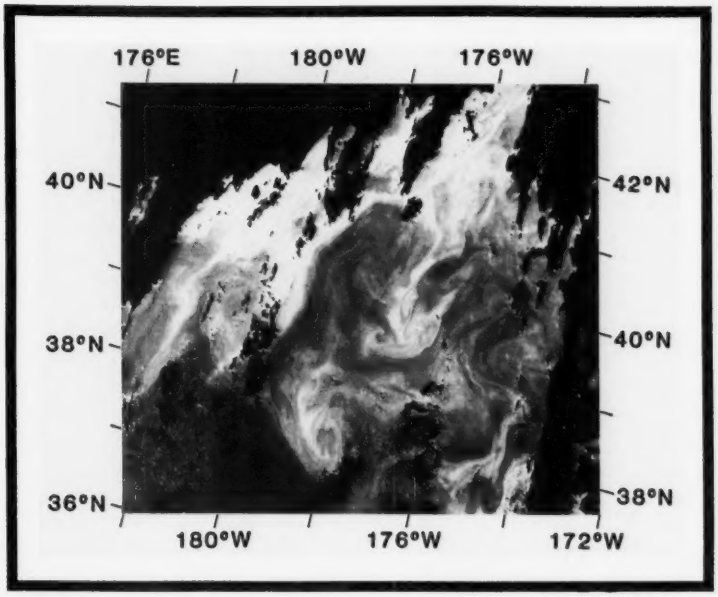


Figure 8. – Phytoplankton pigment concentration in a 600 × 600 km area of the central North Pacific, measured by the Coastal Zone Color Scanner, 30 June 1980. Black = clouds, darkest gray = 0.08 mg m^{-3}, white = 5.7 mg m^{-3}.

fishery operations in these waters has been explored on a limited basis with promising results. Although cloud cover allows only infrequent views of the sea surface, the surface patterns seem to be less dynamic than in coastal waters. Color boundaries are detectable from satellites during all seasons, but pronounced sea surface temperature fronts are not present during summer-autumn due to seasonal warming. However, infrared satellite imagery has been used to locate the subtropical front during winter (Van Woert, 1982) and spring months[3].

In Arctic and subarctic areas, such as the Beaufort Sea and northern Bering Sea, the movements and distribution of sea ice have important influences on the movements of marine mammals. Bowhead and beluga whales make regular seasonal migrations through the shear zones and lead systems that develop in the Arctic pack ice (Braham et al., 1980). In the case of the bowhead whale, the prediction and evaluation of migration paths is important because it is an endangered species and the western Arctic population requires careful annual censusing. Satellite imagery showing ice cover and open-water corridors is used to spot check the sampling design for summer whale counts.

There is potential for similar applications of satellite data in other oceanic and coastal areas, although the relationships between environmental characteristics and marine mammal migrations are not as obvious. For example, the eastern Pacific stock of gray whale, *Eschrichtius robustus,* undergos regular annual migration between summer feeding grounds in the Chukchi Sea and winter breeding grounds in Mexico (Pike, 1962). Satellite coverage of the onset of winter ice cover in the Bering Strait may help explain the environmental signals that initiate the southern migration. Other marine mammals that are important in the region, and that undergo long-distance movements, include: Northern fur seal, *Callorhinus ursinus,* migrating between summer breeding grounds on the Pribilof Islands in the eastern Bering Sea (and on other islands around the Northern Pacific rim) and wintering areas in the Gulf of Alaska and off the U.S. Pacific coast (Fiscus, 1978); humpback whale, *Megaptera novaeangliae,* an endangered species of which the eastern Pacific stock migrates between breeding and calving areas in the Hawaiian Islands and summer feeding grounds in the inland waters of southeastern Alaska (Wolman, 1978); and a number of species of dolphins and porpoise.

Allocation of Sampling Effort

Annual egg and larva surveys of northern anchovy are a regular activity of the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each survey requires 4-5 weeks of ship time to make vertical net tows at 800-900 stations. The accuracy of the estimate of spawning biomass derived from each survey depends on complete coverage of the geographic range of the spawning stock. Without a priori knowledge of this distribution, many extra stations beyond the range limits must be sampled to ensure adequate coverage. We are now investigating the use of satellite imagery to plan egg surveys based on environmental limits characterizing the spawning habitat and detectable from satellites, as described above.

The 1983 survey plan was modified during the cruise using information from satellites. When the cruise began north of Point Conception in February, eggs were found much farther north and offshore than in recent years. Upon examination of AVHRR temperature imagery, we realize that this extension of the spawning range was due to the 1982-83 El Niño event. The cold-water boundary which normally limits

[3]R. Lynn. 1984. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, Ca 92038. Pers. commun.

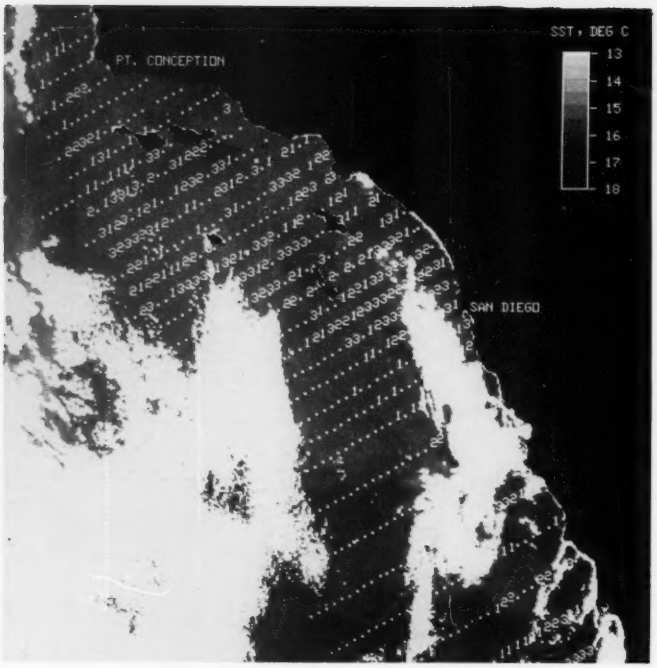


Figure 9.—Northern anchovy egg distribution, 9 February-29 March 1983: •=0, 1=1-3, 2=4-12, 3=13-229 eggs/0.05 m². Sea surface temperature (°C) from NOAA-7 AVHRR, 10 February 1983.

spawning to the southeast of Point Conception had shifted to the north and offshore (Fig. 9, compare with Fig. 3). As a result, the lines of sampling stations were extended farther offshore than originally planned, to ensure coverage of the entire spawning stock.

In another study conducted in June 1980 on the feeding biology of larval jack mackerel, satellite data were used to locate an intensive sampling grid on a temperature front. The front was observed southwest of San Diego in a NOAA-6 AVHRR image obtained over 1 week prior to the cruise, and it persisted during the sampling period (Fig. 10). The front was subsequently found to be related to an important gradient in food availability[4].

These two examples demonstrate how a single satellite image, from data received and processed in a matter of hours, can save days of ship time by locating significant environmental features and permitting efficient allocation of sampling effort. The potential cost savings are obvious, but the real-time use of satellite data requires facilities for direct reception and processing.

Fisheries Aid Charts

Operational applications of satellite data to commercial fishing activities

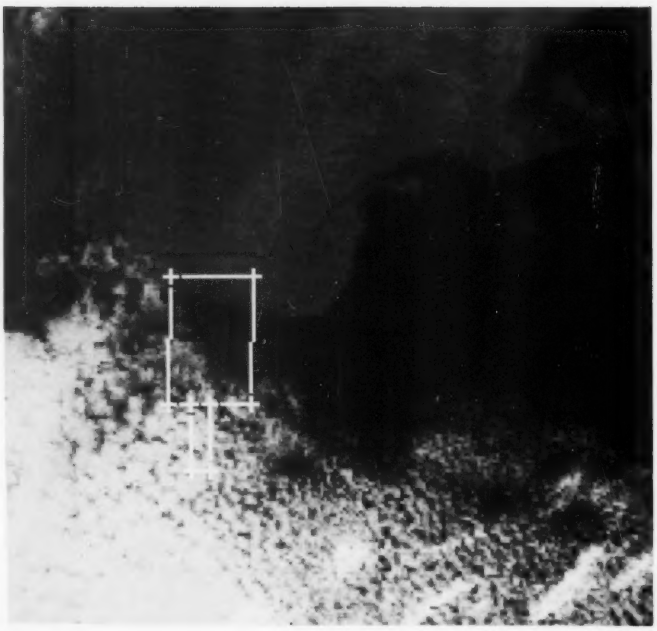


Figure 10.—Uncalibrated NOAA-6 AVHRR channel 4 image off southern California, 5 June 1980. Lighter shades represent cold sea surface temperatures, clouds appear white. Box encloses a 30 × 67 km grid of 41 stations centered at lat. 31° N, long. 120°30′ W.

[4]R. Hewitt. 1983. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038. Pers. commun.

began along the Pacific coast in 1975 (Breaker, 1981) and have now been extended to Alaska. Charts showing sea surface temperature fronts and sea ice visible in satellite AVHRR images, and surface isotherms mapped from satellite and ship data, are produced routinely by NOAA (Fig. 11). The Northwest Ocean Services Center in Seattle produces a chart covering northern California, Oregon, Washington, and southern British Columbia, from lat. 40°N to lat. 52°N. The Satellite Field Services Station in Redwood City, Calif., produces a chart covering central and southern California and northern Baja California, from lat. 28°N to lat. 40°N. Coverage of both charts extends offshore to long. 135°W. They are produced once or twice weekly year-round and are distributed primarily by radio facsimile from the U.S. Coast Guard

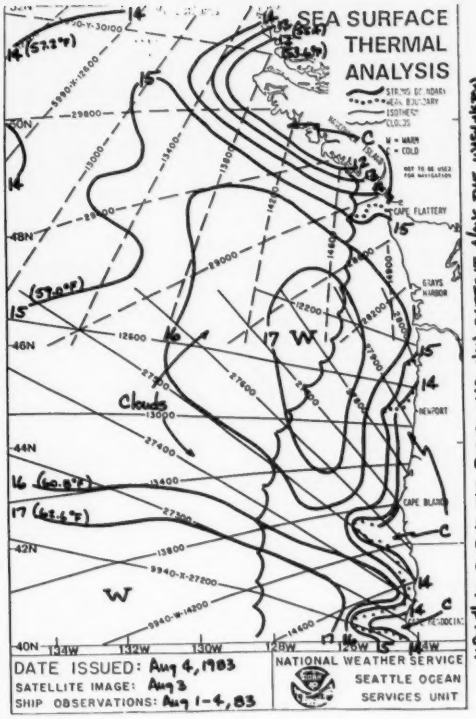
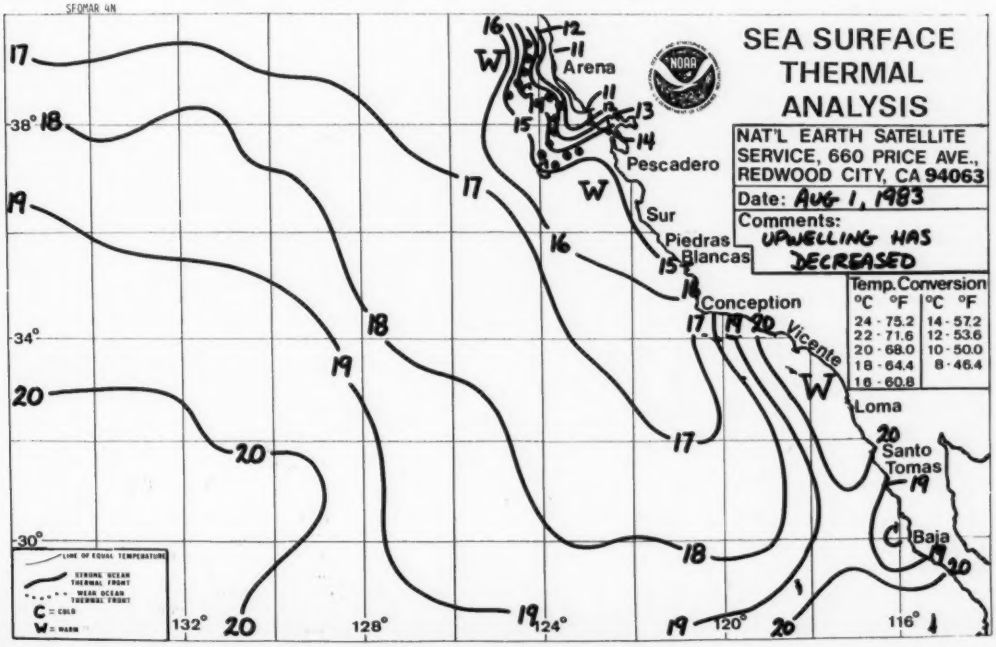


Figure 11.—Sea surface temperature charts produced by the National Weather Service.



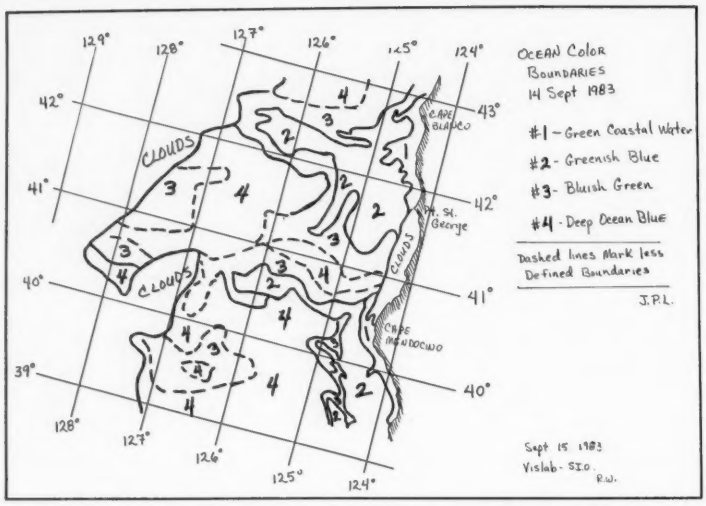


Figure 12.—Ocean color boundary chart off northern California and Oregon (R. Wittenberg, Scripps Visibility Laboratory).

radio station at Point Reyes, Calif. Fishermen use these charts to save time in searching for productive fishing areas associated with frontal features.

The Alaska Ocean Services Unit, located in Anchorage, produces charts covering British Columbia, the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, Chukchi Sea, and Beaufort Sea, from lat. 48°N to lat. 75°N. Charts showing sea surface temperature and sea ice are distributed three times a week; these are intended to aid the safety and efficiency of fishing. Other charts showing 3-and 5-day sea ice forecasts are also distributed daily in winter. Both types of charts are issued by radio facsimile from the U.S. Coast Guard Station at Kodiak, Alaska.

Ocean color boundary charts have been produced experimentally from CZCS data since 1981 in a NASA/Jet Propulsion Laboratory program (Montgomery, 1981). The charts delineate strong gradients in the blue/green color ratio (channel 1/channel 3 radiance). In 1983, charts were produced at almost weekly intervals from May to October (18 charts total), covering coastal areas up to 700,000 km² between Vancouver Island, B.C., and Guadalupe Island, Mex. (Fig. 12). A chart was produced only when a large, cloud-free area was located in a Nimbus-7 pass. The chart was then broadcast on the same or following day to fishing boats by radio facsimile from Point Reyes and La Jolla, Calif. Color photographs of the satellite images were distributed by express mail to various fishing ports and to Sea Grant marine advisors in daily contact with fishermen. The color boundary charts and photographs are used by albacore and salmon fishermen. These fish are sometimes found aggregated along color fronts which do not correspond to temperature fronts.

Conclusions

Satellites have altered our perceptions of the ocean environment through the extensive spatial coverage, temporal continuity, and high resolution of the data they provide. Limited, but useful, applications to several types of problems in fisheries research and operations have been demonstrated. Continued development of these and other applications will depend on inexpensive and convenient access to data and data-processing facilities. Recent trends in the federal budget have not been encouraging. For instance, there are no current prospects for a new ocean color scanner to replace the aging CZCS on Nimbus-7. The commercial utility of satellite data depends largely on near real-time availability to fishermen and other maritime users. In the future, this demand may be met by processed satellite data products tailored more to particular user needs.

Acknowledgments

This work was supported jointly by the Southwest Fisheries Center, La Jolla, Calif., and the Northwest and Alaska Fisheries Center, Seattle, Wash., as a cooperative research project. We thank the many persons who contributed information and ideas for various applications, as well as those who provided technical support at the Scripps Satellite Oceanography Facility and the Scripps Visibility Laboratory. Processing of CZCS data was supported by NASA order W15,334.

Literature Cited

Anonymous. 1984. 1983 in review. Pac. Fish. 1984 Yearb.

Bailey, K. M. 1981. Larval transport and recruitment of Pacific hake, *Merluccius productus*. Mar. Ecol. Prog. Ser. 6:1-9.

Bakkala, R., W. Hirschberger, and K. King. 1979. The groundfish resources of the eastern Bering Sea and Aleutian Island regions. Mar. Fish. Rev. 41(11):1-24.

Bakun, A., and R. H. Parrish. 1982. Turbulence, transport, and pelagic fish in the California and Peru Current systems. CalCOFI Rep. 23:99-112.

Bernstein, R. L. 1982. Sea surface temperature estimation using the NOAA-6 satellite Advanced Very High Resolution Radiometer. J. Geophys. Res. 87:9455-9465.

_____, L. Breaker, and R. Whritner. 1977. California Current eddy formation: Ship, air, and satellite results. Science 195:353-359.

Borstad, G. A., R. M. Brown, D. Truax, T. R. Mulligan, and J. F. R. Gower. 1982. Remote sensing techniques for fisheries oceanography: Examples from British Columbia. NAFO Sci. Counc. Studies 4:69-76.

Braham, H. W., M. A. Fraker, and B. D. Krogman. 1980. Spring migration of the western Arctic population of bowhead whales. Mar. Fish. Rev. 42(9-10):36-46.

Breaker, L.C. 1981. The application of satellite remote sensing to west coast fisheries. J. Mar. Tech. Soc. 15:32-40.

Burns, J. J., L. H. Shapiro, and F. H. Fay. 1981. Ice as marine mammal habitat in the Bering Sea, p. 781-797. *In* D. W. Hood and J. A. Calder (editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 2. Univ. Wash. Press, Seattle.

Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea, p. 383-399. *In* D. W. Hood and E. J. Kelly (editors), Oceanography of the Bering Sea with emphasis on renewable resources, Univ. Alaska, Fairbanks, Inst. Mar. Sci. Occas. Publ. 2.

Fiedler, P. C. 1983. Satellite remote sensing of the habitat of spawning anchovy in the Southern California Bight. (CalCOFI Rep. 24:202-209.

_____. 1984. Satellite observations of the 1982-83 El Niño along the U.S. Pacific coast. Science 224:1251-1254.

Fiscus, C. H. 1978. Northern fur seal, p. 153-159. *In* D. Haley (editor), Marine mammals of eastern North Pacific and Arctic waters. Pac. Search Press, Seattle.

Gordon, H. R., D. K. Clark, J. W. Brown, O. B. Brown, R. H. Evans, and W. W. Broenkow. 1983. Phytoplankton pigment concentrations in the Middle Atlantic Bight: Comparison of ship determinations and CZCS estimates. Appl. Opt. 22:20-36.

Gower, J. F. R. 1982. General overview of the nature and use of satellite remote sensing data for fisheries application. Northwest Atl. Fish. Organ., Sci. Counc. Studies 4:7-19.

Hartt, A. C. 1980. Juvenile salmonids in the oceanic ecosystem—the critical first summer, p. 25-57. *In* W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific. Oreg. State Univ. Press, Corvallis.

Hayman, R. A., and A. V. Tyler. 1980. Environment and cohort strength of Dover sole and English sole. Trans. Am. Fish. Soc. 109:54-70.

Husby, D. M., and C. S. Nelson. 1982. Turbulence and vertical stability in the California Current. CalCOFI Rep. 23:113-129.

Lasker, R. 1981. Factors contributing to variable recruitment of the northern anchovy (*Engraulis mordax*) in the California Current: Contrasting years, 1975-1978. Rapp. P.-v. Reun. Cons. int. Explor. Mer 178: 375-388.

_____, J. Peláez, and R. M. Laurs. 1981. The use of satellite infrared imagery for describing ocean processes in relation to spawning of the northern anchovy (*Engraulis mordax*). Remote Sensing Environ. 11:439-453.

Laurs, R. M., and R. J. Lynn. 1977. Seasonal migration of North Pacific albacore, *Thunnus alalunga*, into North American coastal waters: Distribution, relative abundance, and association with Transition Zone waters. Fish. Bull., U.S. 75:795-822.

_____, and J. T. Brucks. In Press. Living marine resources applications of satellite imagery. *In* B. Saltzman (editor), Satellite Remote Sensing in Oceanography. Advances in Geophysics, Acad. Press, N.Y.

_____, P. C. Fiedler, and D. R. Montgomery. In Press. Albacore tuna catch distributions relative to environmental features observed from satellites. Deep-Sea Res.

McClain, E. P., W. G. Pichel, C. C. Walton, Z. Ahmad, and J. Sutton. 1983. Multichannel improvements to satellite-derived global sea surface temperatures. Adv. Space Res. 2:43-47.

McNutt, S. L. 1981. Remote sensing analysis of ice growth and distribution in the eastern Bering Sea, p. 141-165. *In* D. W. Hood and J. A. Calder (editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 1. U.S. Gov. Print. Off., Wash., D.C.

Mathews, S. B. 1980. Trends in Puget Sound and Columbia River salmon, p. 133-145. *In* W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific, Oreg. State Univ. Press, Corvallis.

Miller, D. R., J. G. Williams, and C. W. Sims. 1983. Distribution, abundance and growth of juvenile salmonids off the coast of Oregon and Washington, summer 1980. Fish. Res. 2:1-17.

Montgomery, D. R. 1981. Commercial applications of satellite oceanography. Oceanus 24(3):56-65.

NASA Satellite Wind Stress Working Group. 1982. Scientific opportunities using satellite wind stress measurements over the ocean. Nova Univ./N.Y.I.T. Press, Fort Lauderdale, Fla., 153 p.

Nelson, C. S., and D. M. Husby. 1983. Climatology of surface heat fluxes over the California Current region. NOAA Tech. Rep. NMFS SSRF-763, 155 p.

Otto, R. S. 1981. Eastern Bering Sea crab fisheries, p. 1037-1066. *In* D. W. Hood and J. A. Calder (editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 2. Univ. Wash. Press, Seattle.

Pike, G. C. 1962. Migration and feeding of the gray whale (*Eschrichtius gibbosus*). J. Fish. Res. Board Can. 19:815-838.

Poole, F. W., and G. L. Hufford. 1982. Meteorological and oceanographic factors affecting sea ice in Cook Inlet. J. Geophys. Res. 87(C3):2061-2070.

Sadler, J. C., L. Oda, and B. J. Kilonsky. 1976. Pacific Ocean cloudiness from satellite observations. Univ. Hawaii, Honolulu, 137 p.

Smith, R. C. 1981. Remote sensing and depth distribution of ocean chlorophyll. Mar. Ecol. Prog. Ser. 5:359-361.

_____, and K. S. Baker. 1982. Oceanic chlorophyll concentrations as determined by satellite (Nimbus-7 Coastal Zone Color Scanner). Mar. Biol. 66:269-279.

Van Woert, M. 1982. The subtropical front: Satellite observations during FRONTS 80. J. Geophys. Res. 87:9523-9536.

Wahle, R. J., and W. S. Zaugg. 1982. Adult coho salmon recoveries and their $Na^+ - K^+$ ATPase activity at release. Mar. Fish. Rev. 44(11):11-13.

Weeks, W. F. 1981. Sea ice: the potential of remote sensing. Oceanus 24(3):39-48.

Wolman, A. A. 1978. Humpback whale, p. 47-53. *In* D. Haley (editor), Marine mammals of eastern North Pacific and Arctic waters. Pac. Search Press, Seattle.

Yamanaka, I. 1982. Application of satellite remote sensing to fishery studies in Japan. NAFO Sci. Counc. Studies 4:41-50.

Marine Bivalve Mollusks as Reservoirs of Viral Finfish Pathogens: Significance to Marine and Anadromous Finfish Aquaculture

THEODORE R. MEYERS

ABSTRACT—Filter-feeding bivalve mollusks can bioaccumulate various disease agents significant in the management of public health. Recent evidence has indicated that marine bivalves can harbor viruses that are virulent for salmonid species. Examples of finfish viruses occurring in shellfish tissues and those that have potential of occurring are presented.

Participation of shellfish in the epizootiology of endemic and/or exotic finfish diseases is possible and should be considered for future management of fish health. To reduce potential introductions of finfish disease agents which may be incidental in shellfish tissues, certification of bivalve stocks is advised before movement into new waters.

Introduction

Epidemiologists have long known that bivalve mollusks are capable of harboring disease agents significant to human health. The mollusks accomplish this phenomenon by filter feeding, whereby seawater is pumped in through the gills which entrap larger planktonic food organisms within the cilia and mucus of the respiratory epithelium (Purchon, 1977). As a result, these mollusks also take in smaller incidental particles including bacteria and viruses suspended in ambient seawater or adsorbed onto the surfaces of organic and inorganic solids.

Consequently, human pathogens including coliform and *Vibrio* species of bacteria as well as polio and hepatitis viruses have been detected in bivalve species from clean and organically polluted waters (Ross, 1956; Mitchell et al., 1966; Hamblet et al., 1967; Liu et al., 1967; Lovelace et al., 1968; Kampelmacher et al., 1972; Ayres, 1975; Thompson and Vanderzant, 1976). Disease outbreaks caused by some of these agents have occurred in the human populace following ingestion of poorly cooked or raw shellfish from contaminated areas (Mason and McLean, 1962; Liu et al., 1967; Sakazaki, 1969.

Recent evidence has shown that marine shellfish are potential reservoirs for certain finfish pathogens through the same bioaccumulation process of filter feeding. This information has some significance when considering finfish disease epizootiology in both marine and freshwater finfish rearing systems having bivalve mollusks directly in the water supply or immediately downstream. Any epizootic occurring within a finfish population can result in the release of high concentrations of the pathogen into ambient water from dead or dying fish. As an example, infectious hematopoietic necrosis virus (IHNV) in hatchery effluents during acute disease outbreaks has been reported at levels as high as 400 p.f.u./ml (Leong and Turner, 1979).

Recorded epizootics in feral finfish populations, though uncommon when fish are normally dispersed, become more evident when fish are concentrated in smaller areas as occurs during periods of spawning or smolt outmigration. As much as 1,600 p.f.u./ml of IHNV has been reported in fresh water near spawning sockeye salmon, *Oncorhynchus nerka,* (Mulcahy et al., 1983). Nearby shellfish beds filtering water contaminated by diseased finfish, would be capable of entrapping the causative disease agent. Filter feeding shellfish can accumulate viruses and bacteria within their tissues at much higher concentrations than present in surrounding seatwater (Mitchell et al., 1966).

The actual concentration in the tissues is dependent upon: The rate at which bivalves pump water through the gills; the concentration and physical characteristics of the microbe in the ambient seawater; and seawater temperature, salinity, and turbidity (Galtsoff, 1964; Hamblet et al., 1967; Liu et al., 1967). Eventually, incidental contaminants are depurated or expelled from the tissues back into the seawater. This virus or contaminant loss occurs over a period of time and is called the depuration rate. This rate is enhanced by exposure of the shellfish to waters free of the contaminant and is proportional to the degree of tissue contamination.

Other factors influencing the depuration rate are the same as those described for bioaccumulation (Liu et al., 1967). Consequently, depuration

Theodore R. Meyers is Assistant Professor of Fisheries, School of Fisheries and Science, University of Alaska, Juneau, 11120 Glacier Highway, Juneau, AK 99801. Views or opinions expressed or implied are those of the author and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

and bioaccumulation rates for a given contaminant vary among species of bivalve and within a species depending upon animal size and environmental parameters influencing animal physiology. Hard clams, *Mercenaria mercenaria* can depurate human polio virus type 1 within 96 hours if placed in clean seawater at 13-15°C (Liu et al., 1967). However, after 40-60 days the European flat oyster, *Ostrea edulis*, still cannot completely depurate certain strains of molluscan IPN viruses, some of which are pathogenic to finfish (Hill and Alderman, 1977; Hill et al., 1982).

Whether a depurated disease agent remains infectious for its natural host depends upon its stability within the environment outside normal host tissues. It is highly probable that beds of filter feeding shellfish contaminated with a stable, viable finfish pathogen could disseminate waterborne infectious particles to other finfish hosts during depuration.

The following discussion presents examples of finfish pathogens actually isolated from bivalve mollusks and others which have potential for bioaccumulation in shellfish tissues. These agents are all viruses which can infect salmonid fishes and at least one centrarchid species. However, other finfish species may also be susceptible to some of these viral agents. There are bacterial agents (*Vibrio* sp., etc.) common to bivalve tissues which are pathogenic for both finfish and other shellfish, but these will not be included herein (Tubiash et al., 1965, 1970; Lovelace et al., 1968; DiSalvo et al., 1978; Leibovitz, 1978; Garland et al., 1983).

Viral Finfish Pathogens Isolated From Bivalves

$13p_2$ Reovirus

A new serotype of reovirus was isolated from juvenile American oysters, *Crassostrea virginica*, held in rearing facilities of two different Long Island, N.Y., shellfish hatcheries (Meyers, 1979; Meyers and Hirai, 1980). The virus, designated as $13p_2$, is very stable, remaining viable in both seawater or oyster tissues for longer than 60 days (Meyers, 1980). It does not replicate in oyster tissues but is infectious for various fish cell lines and for at least two finfish species.

The virus produces a 44 percent mortality in bluegill, *Lepomis macrochirus*, fingerlings causing severe necrotic hepatitis (Meyers, 1980). It also produces chronic self-limiting granulomatous hepatitis and occasional pancreatitis in adult and fingerling rainbow trout, *Salmo gairdneri* (Meyers, 1983). Thus, for rainbow trout, $13p_2$ is weakly virulent for the age classes tested, but its effect on sac fry or on other salmonid species has not been examined. In salmonid aquaculture, this virus may not be significant as a primary pathogen but would contribute to undesirable stress and lowered host resistance to other biological or environmental pressures affecting fish survival.

JOV-1

A second reovirus-like agent, labeled JOV-1, has been isolated from Japanese oysters, *C. gigas*, reared in a Japanese hatchery (Nagabayashi and Mori[1]). Little information is yet available, but apparently the virus is infectious for 10-week-old rainbow trout, producing a 40 percent mortality in infected fish. Fifteen-week-old trout are reported refractory to clinical disease.

IPN Molluscabirnaviruses

Infectious pancreatic necrosis virus (IPNV) was first islated from brook trout, *Salvelinus fontinalis* (Snieszko et al., 1957), and has traditionally caused disease in juvenile salmonids. However, other nonsalmonid strains of IPNV have recently been isolated from many other freshwater and marine finfish species as reviewed by Hill (1982). Many of these new isolates are not responsible for clinical disease in their respective hosts and are variable in their infectivity and virulence for rainbow trout (Hill, 1982). Included among these nonsalmonid IPN viruses are strains which have been isolated from several species of marine bivalves, two species of gastropod, and one decapod crustacean (Hill, 1976a, b; Hill, 1982). Such isolates are nearly all biochemically, biophysically, and serologically (three exceptions represent different serotypes) indistinguishable from reference strains of IPNV in fish. At least eight of these shellfish isolates are pathogenic in rainbow trout fry producing typical clinical signs of IPN disease and fry mortality (Hill, 1982). Definitive evidence is still lacking to substantiate whether such molluscan IPN viruses can replicate in shellfish tissues or are merely bioaccumualted contaminants. Regardless of this final determination, the confirmed pathogenicity of these viruses for rainbow trout and their prolonged stability in shellfish tissues (≥ 50 days; Hill and Alderman, 1977) make them significant disease agents to be considered in the management of anadromous salmonid health.

Viral Finfish Pathogens Having Potential To Occur in Bivalves

There are other viral finfish pathogens which have prolonged viability within the natural environment and could potentially accumulate in nearby mollusk tissues if released from clinically diseased or carrier fish.

CSV

The chum salmon virus (CSV) is another recently discovered reovirus similar in many respects to the $13p_2$ agent. However, CSV is a different virus (Winton[2]) which was isolated

[1]Nagabayashi T., and S. Mori. 1983. XVI Annual Meeting of the Society for Invertebrate Pathology, Cornell Univ., Ithaca, N.Y. Unpubl. abstr.

[2]Winton, J.R. 1984. Department of Microbiology, Oregon State University Marine Science Center, Newport, Oreg. Unpubl. data.

from spawning chum salmon, *Oncorhynchus keta*, caught in Japan. This virus can infect chum, chinook, *O. tshawytscha*; and kokanee, *O. nerka*, salmon fingerlings, producing a self-limiting necrotic hepatitis (Winton et al., 1981). As with the $13p_2$ agent, CSV remains viable for months outside fish host cells. Thus, it could potentially accumulate in filter-feeding bivalve reservoirs near diseased fish hosts. This virus could be significant in salmonid husbandry if it caused similar host debilitation as discussed for the $13p_2$ agent.

IHNV

Infectious hematopoietic necrosis virus (IHNV) is an extremely virulent pathogen of juvenile salmonids in western North America. Consequently, this rhabdovirus is particularly important to Pacific salmon, *Oncorhynchus* spp., and steelhead, *S. gairdneri,* husbandry in the Pacific Northwest and Alaska (Grischkowsky, 1981; Groberg et al., 1982, Groberg, 1983; Rohovec, 1983). Whether IHNV could accumulate in filter feeding mollusks is speculative, but physically and biologically possible.

It is clear that IHN virus can remain infectious for several months in freshwater rivers (Wedemeyer et al., 1978; Mulcahy et al., 1983), and recent laboratory studies indicate detectable levels of virus after 27 and 22 days in estuarine and saltwaters, respectively (Toranzo and Hetrick 1982). It becomes conceivable that high concentrations of IHNV shed by infected spawning salmon or outmigrating clinically diseased smolts could accumulate in marine bivalve mollusks located directly below short stream systems. Shellfish could then participate in waterborne transmission of the virus for a period of time during the depuration process. Although considerable dilution of virus concentrations would be involved, evidence suggests that low levels of infectious particles may be sufficient for transmission of the disease (Mulcahy et al., 1983).

Salmonid IPN Piscibirnaviruses

Although infectious for salmonids, IPN molluscan birnaviruses are less virulent than the true salmonid strains. However, these true salmonid strains are also capable of surviving for long periods of time in fresh, estuarine, and saltwaters (Ahne, 1982; Wedemeyer et al., 1978; Toranzo and Hetrick, 1982). Consequently, they are stable enough in the environment to make possible their bioaccumulation and later dissemination by filter feeding mollusks.

Conclusions

Marine bivalve mollusks are unavoidable in estuarine and salt waters which may be used in the rearing of anadromous fishes or which may be directly downstream of freshwater egg and fry facilities operating on short watersheds. No less abundant are the many freshwater species of filter feeding clams and mussels which populate certain stream and lake bottoms around the world. The established occurrence of certain viral finfish pathogens in common species of marine bivalve mollusks indicates that shellfish could serve two roles in the epizootiology of these disease agents, and possibly others: 1) Shellfish may be seasonal reservoirs for some endemic finfish pathogens originating from finfish epizootics and/or from subclinically diseased "carrier fish"; 2) shellfish could introduce exotic finfish diseases when transported to other waters for commercial or experimental purposes from areas where such agents may be endemic.

In terms of practical fishery management, there is little that could be done about involvement of marine bivalve mollusks in endemic finfish disease epizootiology. However, realization of their potential as disease reservoirs would add a new dimension to the future investigation of certain finfish disease outbreaks.

Conversely, there are obvious prophylactic measures for reducing the possible dissemination of exotic finfish diseases by shellfish introductions into "new" waters. Specific invertebrate diseases, particularly those affecting commercially important marine bivalve mollusks, are becoming increasingly important regarding their geographic containment and control. This concept is emphasized by a growing recognition for the importance of health certification of imported and exported shellfish species (Rosenfield and Kern, 1978; Elston, 1981; Elston[3]). Consequently, if certification procedures are exercised for shellfish pathogens, some additional effort made in screening mollusk tissues for incidental viral finfish pathogens would provide significant protection against the introduction of these agents by movement of shellfish stocks.

Literature Cited

Ahne, W. 1982. Comparative studies on the stability of four fish-pathogenic viruses (VHSV, PFR, SVCV, IPNV). Zentralbl. Vet. Med. B 29:457-476.

Ayres, P. A. 1975. The quantitative bacteriology of some commercial bivalve shellfish entering British markets. J. Hyg., Cam. 74:431-440.

DiSalvo, L. H., J. Blecka, and R. Zebal. 1978. *Vibrio anguillarum* and larval mortality in a California coastal shellfish hatchery. Appl. Environ. Microbiol. 35:219-221.

Elston, R. 1981. Discussion of shellfish certification issues. Aquaculture 7(4): 28-33.

Galtsoff, P. S. 1964. The American oyster, *Crassostrea virginica* Gmelin. U.S. Fish. Wildl. Serv., Fish. Bull. 64:1-4.

Garland, C. D., G. V. Nash, C. E. Sumner, and T. A. McMeekin. 1983. Bacterial pathogens of oyster larvae (*Crassostrea gigas*) in a Tasmanian hatchery. Aust. J. Mar. Freshwater Res. 34:483-487.

Grischkowsky, R. S. 1981. Infectious hematopoietic necrosis virus. *In* R. A. Dieterich (editor), Alaskan wildlife diseases, p. 339-348. Univ. Alaska, Fairbanks.

Groberg, W. J., Jr. 1983. The status of viral fish diseases in the Columbia River Basin. Proc. Viral Dis. Salmonid Fish Columbia River Basin Workshop. Bonneville Power Admin., Portland, Oreg.

_____, R. P. Hedrick, and J. L. Fryer. 1982. Viral diseases of salmonid fish in Oregon. *In* B. R. Melteff and R. A. Nevé (editors), Proc. North Pac. Aquaculture

[3]Elston, R. Pathology and health certification criteria of the Japanese scallop, *Patinopecten yessoensis:* A case history and model approach. Manuscr. Battelle, Pacific Northwest Division, Marine Research Laboratory, 439 West Sequim Bay Rd., Sequim, WA 98382.

Symp., Alaska Sea Grant Rep. 82-2, p. 345-357.

Hamblet, F. E., W. F. Hill, Jr., E. W. Akin, and W. H. Benton. 1967. Effect of turbidity on the rate of accumulation and elimination of poliovirus type 1 by the eastern oyster (*Crassostrea virginica*). *In* Proc. Gulf S. Atl. Shellfish Sanit. Res. Conf., N.H.S., p. 13-23.

Hill, B. J. 1976a. Properties of a virus isolated from the bivalve mollusc *Tellina tenuis* (da Costa). *In* L. A. Page (editor), Wildlife diseases, p. 445-452. Plenum Press, N.Y.

_____. 1976b. Molluscan viruses: Their occurrence, culture and relationships. *In* Proc. 1st Int. Colloq. Invertebr. Pathol., p. 25-29. Kingston, Ont.

_____.1982. Infectious pancreatic necrosis virus and its virulence. *In* R. J. Roberts (editor), Microbial diseases of fish, p. 91-114. Academic Press, N.Y.

_____, and D. J. Alderman. 1977. Observations on the experimental infection of *Ostrea edulis* with two molluscan viruses. Haliotis 8:297-299.

_____, K. Way, and D. J. Alderman. 1982. Further investigations into the pathogenicity of IPN-like viruses for oysters. *In* Proc. III Int. Colloq. Invertebr. Pathol., p. 273-274.

Kampelmacher, E. H., L. M. vanNoorle Jansen, D. A. Mossel, and F. J. Groen. 1972. A survey of the occurrence of *Vibrio parahaemolyticus* and *V. alginolyticus* on mussels and oysters and in estuarine waters in the Netherlands. J. Appl. Bacteriol. 35:431-438.

Leibovitz, L. 1978. A study of vibriosis at a Long Island shellfish hatchery. New York Sea Grant Reprint Series. NYSG-PR-79-02. N.Y. Sea Grant Inst., Albany.

Leong, J., and S. Turner. 1979. Isolation of waterborne infectious hematopoietic necrosis virus. Fish Health News 8:vi-viii.

Liu, O. C., H. R. Seraichekas, and B. L. Murphy. 1967. Viral depuration of the northern quahaug. Appl. Microbiol. 15:307-315.

Lovelace, T. E., H. Tubiash, and R. R. Colwell. 1968. Quantitative and qualitative commensal bacterial flora of *Crassostrea virginica* in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 58:82-87.

Mason, J. O., and W. R. McLean. 1962. Infectious hepatitis traced to the consumption of raw oysters. Am. J. Hyg. 75:90-111.

Meyers, T. R. 1979. A reo-like virus isolated from juvenile American oysters (*Crassostrea virginica*). J. Gen. Virol. 43:203-212.

_____. 1980. Experimental pathogenicity of reovirus $13p_2$ for juvenile American oysters *Crassostrea virginica* (Gmelin) and bluegill fingerlings *Lepomis macrochirus* (Rafinesque). J. Fish Dis. 3:187-201.

_____. 1983. Serological and histopathological responses of rainbow trout, *Salmo gairdneri* Richardson, to experimental infection with the $13p_2$ reovirus. J. Fish Dis. 6:277-292.

_____, and K. Hirai. 1980. Morphology of a reo-like virus from juvenile American oysters (*Crassostrea virginica*). J. Gen. Virol. 46:249-253.

Mitchell, J. R., M. W. Presnell, E. W. Akin, J. M. Cummins, and O. C. Liu. 1966. Accumulation and elimination of poliovirus by the eastern oyster. Am. J. Epidemiol. 86:40-50.

Mulcahy, D., R. J. Pascho, and C. K. Jenes. 1983. Detection of infectious haematopoietic necrosis virus in river water and demonstration of waterborne transmission. J. Fish Dis. 6:321-330.

Purchon, R. D. 1977. The biology of the mollusca, 2nd ed. Pergamon Press, Oxf., 596 p.

Rohovec, J. S. 1983. Current fish disease control policies affecting the Columbia River Basin. Proc. Viral Dis. Salmonid Fish Columbia River Basin Workshop. Bonneville Power Admin., Portland, Oreg.

Rosenfield, A., and F. G. Kern. 1978. Molluscan imports and the potential for introduction of disease oganisms. *In* R. Mann (editor), Exotic species in mariculture, p. 165-183. MIT Press, Cam., Mass.

Ross, B. 1956. Hepatitis epidemic conveyed by oysters. Sven. Larkartidn 53:989-1003.

Sakazaki, R. 1969. Halophilic Vibrio infections. *In* H. Riemann (editor), Food-borne infections and intoxications, p. 115. Acad. Press, N.Y.

Snieszko, S. F., E. M. Wood, and W. T. Yasutake. 1957. Infectious pancreatic necrosis in trout. Am. Med. Assoc. Arch. Pathol. 63:229-233.

Thompson, C. A., and C. Vanderzant. 1976. Relationship of *Vibrio parahemolyticus* in oysters, water and sediment, and bacteriological and environmental indices. J. Food Sci. 41:117-122.

Toranzo, A. E., and F. M. Hetrick. 1982. Comparative stability of two salmonid viruses and poliovirus in fresh, estuarine and marine waters. J. Fish Dis. 5:223-231.

Tubiash, H. S., P. E. Chanley, and E. Leifson. 1965. Bacillary necrosis, a disease of larval and juvenile bivalve molluscs. J. Bacteriol. 90:1036-1044.

_____, R. R. Colwell, and R. Sakazaki. 1970. Marine vibrios associated with bacillary necrosis, a disease of larval and juvenile bivalve mollusks. J. Bacteriol. 103:271-272.

Wedemeyer, G. A., N. C. Nelson, and C. A. Smith. 1978. Survival of the salmonid viruses infectious hematopoietic necrosis (IHNV) and infectious pancreatic necrosis (IPNV) in ozonated, chlorinated and untreated water. J. Fish Res. Board Can. 35:875-879.

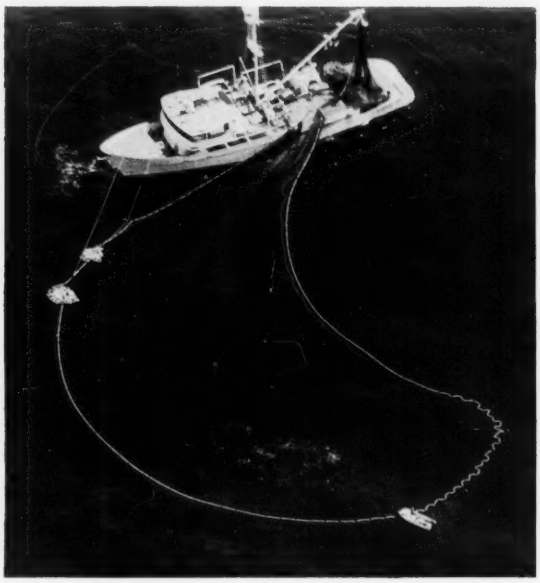
Winton, J. R., C. N. Lannon, J. L. Fryer, and T. Kimura. 1981. Isolation of a new reovirus from chum salmon in Japan. Fish Pathol. 15:155-162.

The "Tuna-Porpoise" Problem: NMFS Dolphin Mortality Reduction Research, 1970-81

JAMES M. COE, DAVID B. HOLTS, and RICHARD W. BUTLER

Introduction

Nearly 15 years have passed since the National Marine Fisheries Service (NMFS) first became concerned with reducing incidental dolphin[1] mortality in the U.S. tuna purse-seine fishery. This paper is presented as an overview of NMFS' applied research on this problem. The major portion of this research was conducted at the La Jolla Laboratory of the NMFS Southwest Fisheries Center (SWFC). This paper is not intended to be a complete history of the program, but rather is a summary and index of the major research conducted by the SWFC over the full course of the program's existence from 1970 to 1981. A glossary (Table 1) and a bibliography of NMFS publications and reports on dolphin mortality-reduction research are included.



A typical purse seine during the backdown procedure. The Vessel is a 525-ton class III seiner which is beginning backdown with about 200 spotted dolphins in the net.

Background

Purse seining for yellowfin tuna, *Thunnus albacares,* in the eastern tropical Pacific reached commercial proportions in the 1950's (McNeely, 1961). This fishing method involved the incidental deaths of many thousands of dolphins, a fact not widely known until the late 1960's (Perrin, 1969; 1970). In 1969 a modest research program was formed within the National Marine Fisheries Service (then named the Bureau of Commercial Fisheries) to investigate the specific nature of what has since come to be known as the "tuna-porpoise" problem. From its inception, this research program, located at the NMFS Southwest Fisheries Center, has had a portion of its resources dedicated to research on the reduction of incidental dolphin mortality in the tuna fishery.

The Marine Mammal Protection Act (MMPA) of 1972 charged the NMFS with the responsibility of carrying out provisional regulations designed to reduce dolphin mortality and injury to the lowest practicable level. In 1972, while this act was being drafted, NMFS convened a group of marine mammal scientists, fishery biologists, and policy specialists, known as the NOAA Tuna-Porpoise Review Committee, to prepare an action plan addressing the tuna-porpoise problem. The report of this group[2] provided general guidelines under which virtually all subsequent NMFS dolphin related research has

[1]Three species of pelagic dolphins (commonly called "porpoise" by tuna fishermen) were primarily involved in this research. They are, in order of decreasing importance, the spotted dolphin, *Stenella attenuata;* spinner dolphin, *S. longirostris;* and the common dolphin, *Delphinus delphis.* Common names in this paper for marine mammals follow the terminology of the International Whaling Commission and the U.S. Marine Mammal Commission.

James M. Coe is with the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. David B. Holts is with the Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038 and Richard W. Butler, then with the SWFC, is at Carson City, NV 89701.

[2]Report of the NOAA Tuna-Porpoise Review Committee, Sept. 8, 1972. U.S. Dep. Commer., NOAA, NMFS, Southwest Fish. Cent., La Jolla, Calif., 63 p.

Table 1.—Glossary of tuna seining terms and definitions adapted from F. M. Ralston (editor), 1977. A workshop to assess research related to the porpoise/tuna problem. SWFC Admin. Rep. LJ-77-15, 119 p.

Apex flapper: An experimental modification to the super apron consisting of a series of overlapping, trapezoidal pieces of 1¼-inch mesh. These panels were placed above the corkline at the apex of the backdown channel to provide a visual barrier to the tuna and, at the same time, be permeable to dolphins.

Apron: A trapezoidal appendage sewn to the top edge of the uppermost dolphin safety panel(s) of a purse seine. Before the apron can be installed the corkline must be cut from the safety panel. The corkline is subsequently reattached to the sides (which are equilateral) and the top of the apron, the base of the apron having been attached to the safety panel. The apron produces a ramplike shallowing of the backdown area, reduces canopies, and reduces the incidence of tuna mixing with the dolphins in the release area during backdown.

Backing down (backdown): A process whereby the corkline of the purse seine can be submerged and pulled from under the dolphins with the application of reverse engine power by the seiner. This is a fundamental technique for releasing dolphins from the net.

Bridles: Typically, these are sections of chain that are attached at both ends to the seine chainline. They are cut at a length that allows draping of the bridle below the chainline; a split-link is attached at the center of the bridle and a pursing ring is tied to this link (also see towing bridles).

Bunches: These are large clumps of bunched corkline. They are pulled using an auxiliary bunch-line (like a draw string) that runs through small (3" diameter) rings which are tied to the corkline. Bunches are useful in 1) removing excess slack in the corkline (which can lead to canopies and entrapment) and 2) maximizing the bouyancy of the net going into the sacking-up phase (to prevent sinkage and loss of fish).

Canopy: This is a configuration where the webbing blossoms out beyond the corkline due to currents or other adverse conditions. Dolphins in canopies frequently can't find the way back to the surface to breathe due to the sometimes convoluted shape of the canopy. Canopies can also be caused by net collapses, where the corkline comes together and forces dolphins into contact with the meshes and greatly reduces available surface area.

Chainline (leadline): This is a section of chain that runs the length of the bottom of the net. It is attached to the selvage on the lower edge of the bottom strips of webbing and provides the weight necessary to sink the webbing.

Chute: This is a trapezoidal section of webbing with equilateral sides. It is located atop the apron, but below the corkline. It further optimizes the ramp-formation characteristics of the apron.

Collapse: This is a situation where the corkline comes together, restricting the dolphins' access to the surface. Severe collapse, involving large portions of the net, can result in high dolphin kills. The timely use of speedboats pulling on towing bridles has proven to be an effective measure in reducing the incidence of collapse.

Downhauls (downhaul gate): For this application, a series of rope bridles is attached to the seine's corkline, each attached to a vertical line leading to an anchor point on the webbing directly below. Shortening the vertical line causes the corkline at the bridle above to submerge during the pursing operation to permit dolphin release.

Encirclement: This refers to the stage of the set where the target (either dolphins and tuna, "schoolfish" tuna, or log-associated fish) is surrounded by the net or a combination of the net and towline.

Entanglement: This refers to dolphins being physically stuck in the webbing of the net (or the corkline) by a part of their body such as beak, flippers, flukes, or dorsal fin.

Entrapment: This refers to a situation within the seine where the dolphins are forced into contact with the webbing due to collapse or canopy formation.

Fine mesh: This term is typically used to specify 1¼-inch stretched mesh webbing.

Hand holds: On the purse-seine corkline, spaces between adjacent floats at regular intervals (about 1 fathom) where the webbing is not laced to the corkline. These facilitate the orderly stacking of the corkline during net retrieval but also provide openings where dolphins can become entangled.

Hang-in: This refers to the systematic attachment of webbing to a fixed shorter length of bordering line or chain, usually (in purse seines) in the horizontal plane, to allow the meshes to open vertically (hang) without deforming the bordering line.

Medina panel: This is a 2-inch mesh safety panel that is placed in the net to reduce dolphin entanglement during backdown. Generally one strip deep, it surrounds the apex of the backdown channel, the area where dolphins are most likely to come into contact with the net.

Ortza: This refers to either of the ends of the purse seine which are reinforced. The typical seine net tapers up gradually from the maximum depth to the pointed, wing-like ortzas.

Purse cable: This cable runs through the purse rings, which are connected to the chainline by the bridles. By attaching both ends of this cable to the winch, the rings may be gathered and lifted to the boat. This closes the bottom of the net and precludes subsurface escape of fish.

Purse rings: The rings are attached to the bridles and are gathered by the purse cable. The use of rings permits the pulling and lifting force of the winch to be equally distributed along the chainline during pursing.

Pursing: The process of gathering and lifting the bottom of the net.

Reversed bunchlines: These are ropes that run through small rings which are attached to the corkline of the seine. At one end they are secured to the corkline; a small float is attached to the other end. These lines are 20-50 fathoms long and are arranged so the floats of adjacent bunchlines are close together (1 fathom). A speedboat can secure both end-floats of these lines and, by pulling them away from the net, effectively hold the net, thereby preventing collapse in that area.

Roll-net (net roll): After the net has been pursed, the towing or stern end is led through the power block. The power block begins turning and lifting the net out of the water onto the seiner, where it is methodically stacked for the next set. The net is rolled from the stern ortza until the catch is compressed due to the diminishing underwater volume. This results in the catch being rolled into the sack (which is near the bow ortza). In sets involving dolphins, the net is rolled until the amount of net left in the water is proper for backdown. The roll-net process stops, the net is tied down, backdown takes place, and roll-net begins again.

Roll-up: A roll-up is a recurring type of malfunction whereby webbing and cable become tangled and usually results in a delay of the set (described in text above). The period of time needed to remedy the roll-up varies as a function of its severity and can last from a few minutes to several hours. Pursing of the net is slowed drastically or stopped completely. Canopy formation and/or net collapse may occur as a result of the delay if appropriate precautions are not followed.

Sacking up: When the net has been rolled so that the fish are aggregated, a lifting process begins in which the net is pulled over the rail of the seiner. The net is made shallower by this process, and the fish are further confined and trussed up to the surface where brailing can begin. Normally an auxiliary winch and a choker winch are used to hold the load of the fish being sacked up.

Skiff: The skiff is an auxiliary boat carried on the stern of the seiner. It is generally 20-25 feet long and has a beam of 15-18 feet. The skiff is used in three essential components of the set: 1) it holds the bow ortza during the setting or laying out of the net, making it possible to retrieve both ends of the net after encirclement, 2) it is used with a tow rope (generally polypropylene) to pull on the seiner and optimize its position relative to the net, and 3) it is used to sack up the catch, proving necessary flotation for the catch and a platform for the brailing operation.

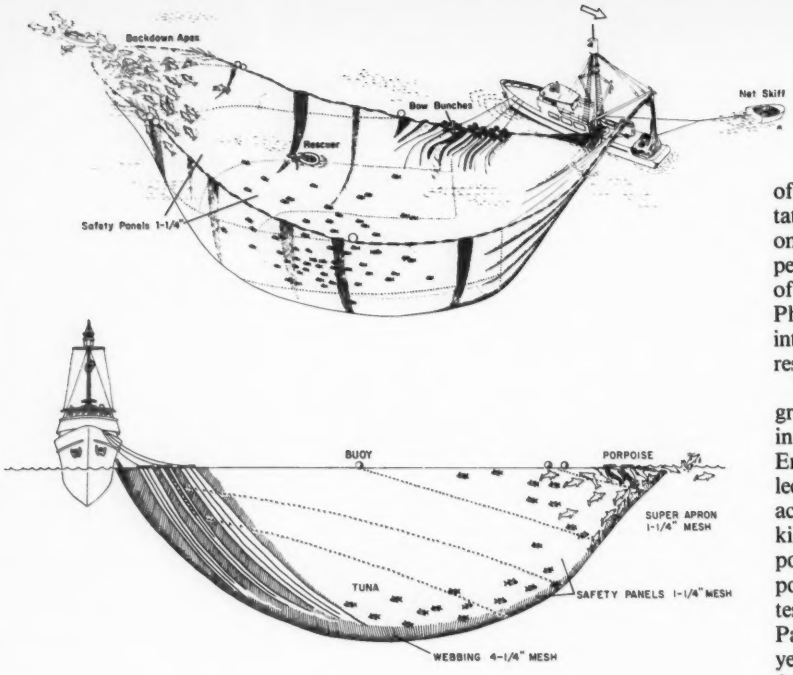
Speedboats: The speedboats carried on seiners are generally 16-18 feet long with a single seat. They are powered by 65-100 horsepower outboard motors and are designed for high-speed, open-ocean operation. Speedboats are used for many different processes in the set: 1) The chase and directing of the dolphin school prior to the set, 2) "patrolling" of the net after encirclement to keep dolphins away from hazard areas, 3) pulling on the net's reverse bunchlines or corkline to prevent collapse, 4) assisting in the process of pulling bow bunches by clearing the bunchlines and tangled corks, and 5) providing a platform for the hand release of dolphins throughout the set, but primarily during and after backdown. Tuna seiners usually use 4-5 speedboats in the course of a dolphin set.

Tie-down point: When a seiner prepares to back down, both ends of the net must be secured in order to withstand the resultant load. Canopy formation is minimized during backdown if the proper amount of net between the outermost bunch and the stern is left in the water. This optimal condition can be attained on every set if the tie-down points are marked. This can be done by painting the proper cork on the corkline (which is secured with the choker winch) and painting marks on the line controlling the outermost bow bunch.

Towline: The towline is attached to the stern ortza and permits retrieval of the ortza in sets where the circle described by the set has a longer circumference than the length of the net.

Winch: This refers to the large hydraulically operated main winch that is used to purse the net. It has three drums; one is used to retrieve towline, and the other two control the ends of the pursing cable.

Zipper: The zipper is a line (usually braided nylon) that runs through small rings which are tied to the net. One end is attached to the corkline at midnet. The other end is attached to the center of the chainline. When the rings have been loaded on the ring stripper, the chainline end of the zipper can be pulled. The midnet corks are pulled to the boat and the net is bisected on a vertical axis. The zipper is used to "cut" the net in sets where the catch is too large to sack up in one bunt without risking a rip and loss of fish. "Cutting" the net with the zipper makes it possible to sack up twice. After making the cut, the fish are divided into two sections of the net, each with a bunt. Part of the catch can be sacked up and brailed aboard from the midnet bunt. After these fish are loaded, this bunt is released. The remaining fish can be rolled to the main bunt and loaded in the normal manner.



Two views of typical purse seines during the backdown procedure.

been conducted. These guidelines specifically recognized the urgent need for research to develop gear and methods to reduce the incidental dolphin-kill rates.

The urgency of this research stemmed from two separate instances. First, biologists and government officials became concerned that the affected dolphin populations were being depleted by the apparent high kill rates. Second, the MMPA provided NMFS with the authority to severely curtail or even close down the U.S. tuna industry to prevent further killing of marine mammals. The Review Committee recognized that a possible result of curtailing or closing the U.S. tuna fishery would be the transfer of vessels to foreign registry. If this were to happen, there would be little likelihood of satisfactorily rectifying the tuna-porpoise problem. Therefore, the Committee recommended that the highest priority should be the development of fishing tactics and gear innovations that would not lessen the effectiveness of the current method of catching tuna. In addition, the innovations would not be too costly and would ultimately permit the harvest of tuna without endangering the dolphin stocks. Through this approach, foreign fleets would adopt these economically feasible innovations, the U.S. tuna fisheries would be maintained, and realistic progress would be made toward marine mammal protection.

The Committee envisioned two mortality reduction research phases. Phase-I was the immediate development and transfer into practice of methods and gear to achieve the lowest possible dolphin kill rates using standard purse seining methods. Phase-II was the research and development of fishing systems that would allow the take of yellowfin tuna without capturing the associated dolphins. The Phase-II work was to be based on behaviorial differences (natural or induced) between the tuna and dolphins and the design of compatible fishing systems to take advantage of those differences.

The need for immediate results in mortality reduction and the limitation of available research funds necessitated the concentration of resources on Phase-I activities. This situation persisted from 1970 through the end of fiscal 1977 when the beginnings of Phase-II research were incorporated into the existing mortality reduction research program.

In general, the NMFS research program has relied on several approaches in finding solutions to the problem. Enough detailed data had been collected by 1974 to allow a reasonably accurate evaluation of the causes of kill in nets. These data helped to pinpoint the major causes of kill so that potential solutions could be devised, tested, and transferred to the fleet. Particularly important in the early years (1970-74) was the search for effective net- and vessel-handling methods and gear refinements employed by a few captains and the dissemination of information on these methods to others in the tuna fleet. In the latter years of the program (1978-81), efforts to quantify and understand the basics of net behavior, especially during backdown (Coe and Sousa, 1972), led to further refinements in the backdown technique and the net design. Data on causes of kill, fleet performance, and net-handling techniques were gathered through both the voluntary observer program (1971-75) and the subsequent mandatory observer program (1976 through 1982) (NMFS, 1975). Experimental gear and methods were tested and modified at sea aboard tuna vessels, including a vessel that was donated by the tuna industry for 1 year (the 1978 "Dedicated Vessel" Program).

Table 2 lists all NMFS charter cruises which conducted mortality-reduction studies during the decade. Technology transfer and dissemination of information on improved mortality-reduction methods were accomplished through the observer program, formal presentations to industry groups, direct waterfront con-

tacts, extension services to the fleet, distribution of published literature, and contact with the Industry's Expert Skippers' Panel (Federal Register, 1977). Regulatory and enforcement regimes established under the MMPA and managed by the NMFS Southwest Regional Office (beginning in 1976) also assisted in the incorporation within the fleet of a wide range of gear and procedures for mortality-reduction.

The total annual dolphin mortality in the U.S. fishery was estimated to be 315,000 in 1970 (footnote 2); by 1980 it had been reduced to an estimated 16,900[3] (Allen and Goldsmith, 1982). These results stem not only from the application of research results, but also from extremely complex social, economic, and legal changes and processes affected through the efforts of many people in both the private and public sectors. In its direct research efforts on mortality-reduction methods and gear, NMFS alone has spent 2.4 million dollars, fielded 3,100 man-days at sea, and employed about 60 temporary and permanent employees. Because of the complex nature of the overall societal effort, the contribution of research to the reduction in total annual dolphin mortality is difficult to estimate.

The Nature of the Dolphin Problem

Operational Complexity.

Ten years of research have clearly shown that the problem of the incidental dolphin kill is multifaceted and not amenable to "key-discovery" solutions. Aside from occasional shark attacks and encounters with vessel power equipment (speedboats, powerblock, net skiff, brailer, etc.), death of dolphins by suffocation is the rule. Dolphins are killed when confined by the net in such a way that they are unable to rise to the surface to breathe. The animals are either entangled individually in the meshes or are entrapped singly or in groups by folds or "canopies" of net webbing. The probability that animals will become entangled or entrapped depends upon the configuration of the net, the number of dolphins and amount of tuna captured in the net, the behavior of the captured dolphins, the skill of the vessel operator, and the condition of the net and equipment.

Figure 1 is a simplified scheme showing the relationships between circumstances and processes which affect the kill and release of dolphins.

[3]Estimate includes 5 percent upward adjustment for seriously injured dolphins assumed to have died after release.

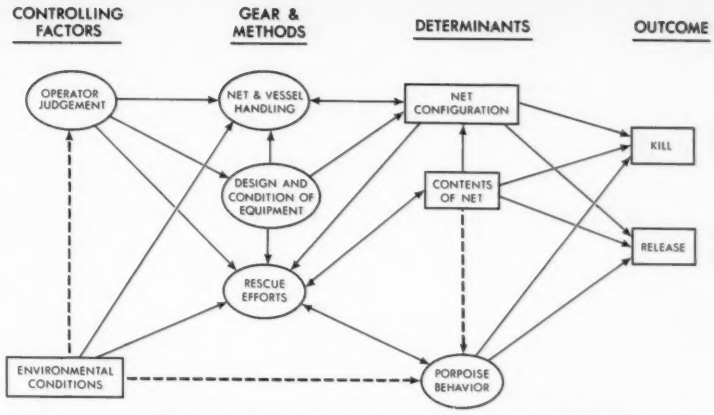


Figure 1.—A generalized schematic showing the operational interrelationships among factors controlling the use of gear and methods to influence the determinants of successful dolphin release from a tuna purse seine. Ovals indicate areas of NMFS applied research and education efforts. Broken lines between blocks indicate uncertainty in the nature of the relationship.

Table 2.—NMFS charter cruises with mortality reduction objectives.

NMFS cruise no.	Vessel	Dates	Cruise leader
	AVR *Miss Behavior*[1]	15 June -20 June 1970	W. F. Perrin
	RV *Cromwell*[1]	3 Sept. - 4 Sept. 1970	W. F. Perrin
	Conquest	21 Dec. -22 Dec. 1970	W. F. Perrin
11	*San Juan*	14 May -15 May 1971	W. F. Perrin
12	*Westport*	7 Sept. - 8 Sept. 1971	W. F. Perrin
13	*Queen Mary*	16 Nov. -17 Dec. 1971	W. E. Evans
26	*Independence*	27 Sept. -29 Oct. 1972	R. L. McNeely
27	*Independence*	11 Dec. -17 Dec. 1972	R. L. McNeely
28	*Independence*	1 Jan. -13 Feb. 1973	F. Wathne
51	*John F. Kennedy*	23 May - 5 June 1973	R. L. McNeely
52	*Trinidad*	16 Oct. -11 Nov. 1973	R. L. McNeely
53	*John F. Kennedy*	10 Nov. -15 Dec. 1973	J. Jurkovich
96	*South Pacific*	28 Oct. - 1 Dec. 1974	R. L. McNeely
97	*J. M. Martinac*	30 Oct. -21 Dec. 1974	D. J. Twohig
131	*South Pacific*	3 July -25 Aug. 1975	F. M. Ralston
132	*Bold Contender*	28 Sept. - 4 Dec. 1975	R. L. McNeely
133	*Eastern Pacific*	29 Sept. - 6 Dec. 1975	J. Jurkovich
207	*David Starr Jordan*[1]	5 Oct. -18 Nov. 1976	D. B. Holts
208	*Elizabeth C. J.*	11 Oct. - 9 Dec. 1976	W. F. Perrin, J. M. Coe
265	*Margaret L.*	19 May -11 Sept. 1977	R. W. McLain
328	*Margaret L.*	27 Oct. -22 Dec. 1977	J. M. Coe
329	*Maria Marie*	2 Nov. -25 Dec. 1977	C. B. Peters
375	*Queen Mary*	26 Jan. -16 March 1978	D. B. Holts
395	*Queen Mary*	17 Apr. - 5 June 1978	J. M. Coe
411	*Queen Mary*	22 June -18 Aug. 1978	F. T. Awbrey, D. A. Bratten
434	*Queen Mary*	12 Sept. -31 Oct. 1978	J. E. Powers
451	*Queen Mary*	11 Nov. - 9 Dec. 1978	D. B. Holts
517	*Cabrillo*	19 May -19 July 1979	G. L. Anderson
552	*Cabrillo*	18 Aug. - 7 Oct. 1979	M. Deerman
565	*Maria C. J.*	17 Sept. -22 Nov. 1979	J. M. Coe
658	*Maria C. J.*	22 Sept. -28 Dec. 1980	J. M. Coe

[1]NMFS research vessel.

Almost every block in Figure 1 represents from three to several dozen components that interact within the block, and with many of the components of the other blocks. Although a complete expansion of this diagram to show all of the known interactions at each level would yield a tangled mass of blocks and arrows, it would serve to illustrate the true complexity of the problem and the degree of skill and attention required of an operator to successfully negotiate sets on dolphins day after day. The estimated annual mortality figures shown in Figure 2 and Table 3 illustrate the effectiveness of the U.S. regulations on gear and methods imposed on operators in 1976, 1977, and 1978, and demonstrate the operators' ability and willingness to incorporate the regulations into their operations. Table 4 indicates a general decrease in the percentage of disaster sets—sets in which a kill of 16 or more dolphins occurred. One would expect to see occasional sets with high kills even from captains with otherwise excellent performance records since environmental conditions, most dolphin behavior, and certain equipment failures cannot be controlled. The number of disaster sets fell to less than 3 percent of all observed sets in 1980. Under the present level of technology, further significant reductions in this percentage appear remote.

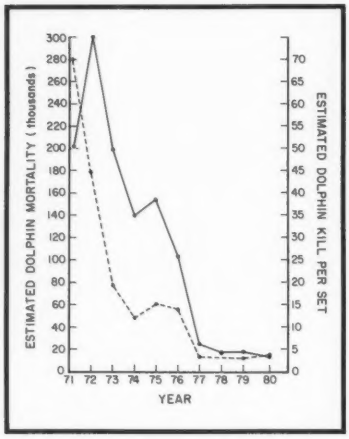


Figure 2.—Estimated annual dolphin mortality (solid line) and kill-per-set (broken line) by the U.S. tuna purse seine fleet.

Pinpointing Causes of Kill

The essential information on specific causes of dolphin mortality and the magnitude of the contribution of each cause was gathered in a variety of ways. In the early years of the program, research directions were based primarily on the field observations of the sea-going staff and on reports from vessel captains. Much of this information was never recorded except in the minds of the researchers because the urgency of the work precluded preparation of lengthy official documents and reports. As the sophistication of the whole "tuna-porpoise" program increased, placing observer records into computers made it possible to store and recover more data related to causes of mortality and fleet performance. Since 1976-77, this data-management capability has

Table 3.—Summary statistics of dolphin sets from NMFS observer trips, 1971-80. Numbers in parentheses are sample sizes.

Statistic	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1. Total number of dolphin sets	51	273	705	993	948	754	3,408	1,811	2,036	1,007
2. Number of pure spotted-dolphin sets	23	117	302	425	361	255	1,093	931	1,015	587
3. Number of pure spinner-dolphin sets	0	0	17	15	11	9	14	8	7	6
4. Number of mixed spotted and spinner sets	25	132	279	365	412	399	756	680	503	257
5. Number of common-dolphin sets	2	23	105	142	96	55	10	4	7	1
6. Number of others and unidentified dolphin sets	1	1	2	46	68	36	1,535	188	504	156
7. Average tons of yellowfin per set	18(48)	20(272)	14(705)	11(993)	13(948)	13(754)	12(3,408)	11(1,811)	11(2,035)	10(1,006)
8. Average number of dolphins caught per set	219(48)	486(245)	378(705)	355(980)	634(947)	816(720)	813(3,107)	821(1,612)	658(1,797)	643(905)
9. Average dolphin school size per set[1]	298(48)	1,007(239)	907(703)	1,163(866)	1,216(945)	1,419(734)	1,656(3,205)	1,446(1,669)	1,170(1,870)	1,054(935)
10. Average dolphin kill per set	70(48)	43(272)	19(705)	12(993)	16(947)	14(754)	3(3,408)	4(1,809)	3(2,034)	4(1,006)
11. Average dolphin kill per ton of yellowfin tuna	3.8	2.2	1.3	1.1	1.3	1.1(754)	0.2(3,408)	0.4(1,809)	0.2(2,033)	0.3(1,006)
12. Percent dolphins killed of dolphins caught	31.9	8.9	4.9	3.4	2.5	1.8(720)	0.4(3,107)	0.5(1,611)	0.3(1,797)	1.6(904)
13. Percent of school captured[1]	73.5	48.3	41.7	30.5	52.2	57.4(719)	49.6(2,984)	57.5(1,540)	58.3(1,730)	63.1(885)
14. Percent of school killed[1]	23.5	4.3	2.1	1.0	1.3	1.0(734)	0.2(3,205)	0.3(1,667)	0.2(1,868)	0.4(934)
15. Percent of sets catching yellowfin tuna	92(48)	89(273)	82(705)	74(993)	82(948)	83.3(754)	84.7(3,408)	85.3(1,811)	87.3(2,035)	91.3(1,006)
16. Percent of sets catching dolphins	100(48)	91(273)	86(705)	83(993)	91(947)	91.4(720)	95.5(3,107)	97.4(1,612)	97.2(1,797)	99.3(905)
17. Percent of sets catching dolphins with zero killed	2(48)	12(248)	18(601)	22(827)	24(863)	30.4(658)	56.5(2,968)	58.4(1,569)	71.4(1,746)	67.5(898)

[1]Estimates generally have a low precision.

Table 4.—Summary statistics of sets with dolphin kill greater than 16, from NMFS-observed trips. Number of dolphins killed.

Year	Number of sets (%)	Total kill	Backdown canopies				Pre-B.D. net collapse	B.D. channel collapse	Malfunction mortalities	All other causes	Unknown
			Bow	Stern	Other	Total					
1977	135(4.0)	5,277	749	1,539	774	3,062	440	346	329	339	780
1978	73(4.6)	4,932	478	486	872	1,836	1,897	338	397	243	221
1979	54(3.5)	2,879	960	173	43	1,176	284	326	84	925	84
1980	30(2.9)	2,647	106	206	220	532	29	1,504	303	140	139
Total	292(3.9)	15,735	2,293	2,404	1,909	6,606	2,650	2,514	1,113	1,647	1,224
Percent of total kill		100	15	15	12	42	17	16	7	10	8

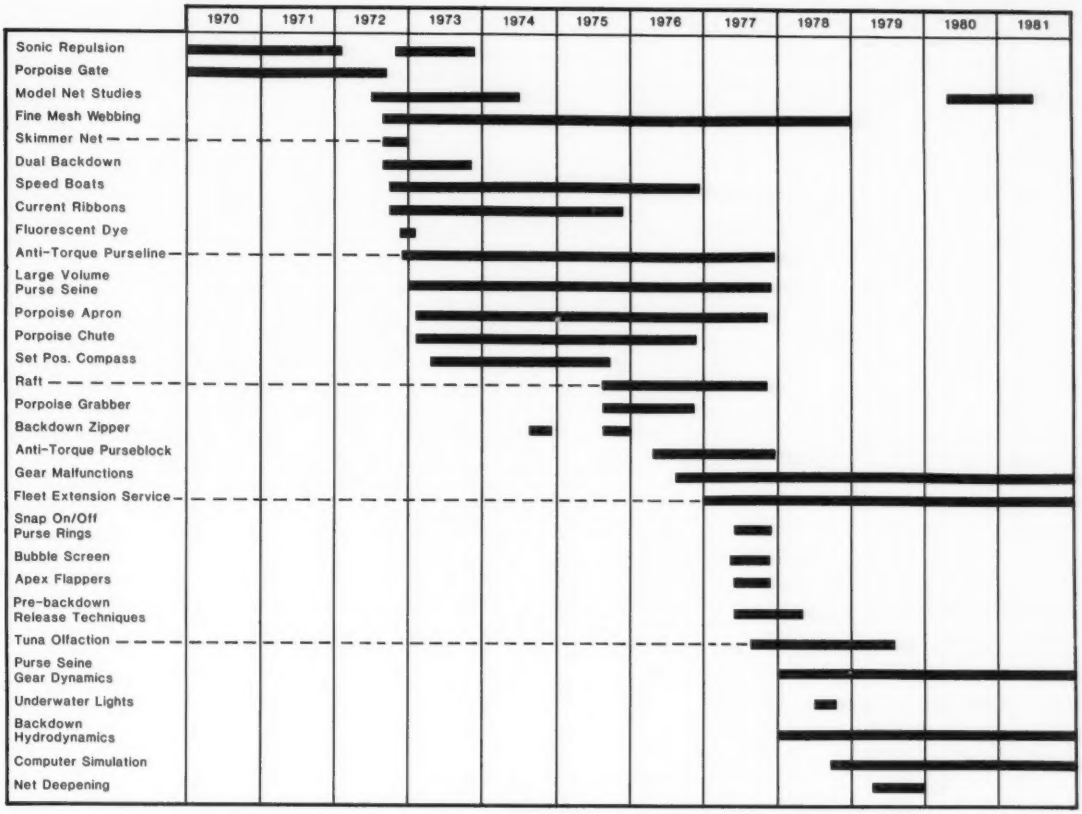


Figure 3.—Areas of NMFS dolphin mortality reduction research since 1970, by subject areas.

allowed analyses that assess the performance of experimental gear and techniques and that allow tracking of the major causes of dolphin kill. Table 4 shows the primary causes of kill for disaster sets from 1977 through 1980. The primary causes are related to net configuration (i.e., backdown canopies, prebackdown net collapse, backdown channel collapse). Most of the malfunction-related kill is also due to resultant net-configuration problems. An example of an "other" cause of mortality is when the dolphins are "sacked-up" in the bunt with the tuna and suffocated. The unknown causes of kill are, for the most part, related to the behavior of the captured dolphins.

Specific Research Efforts

Shown in Figure 1 are the areas in which NMFS has focused its research. Net and vessel handling, so as to minimize net-configuration problems, was of primary importance along with the development and improvement of effective rescue and release techniques. Some effort has gone into the search for methods of eliciting differential responses of tuna and dolphins that could be employed in separating them before or during a set. In this section, the specific areas of research are discussed. They have been categorized according to the functional areas presented in Figure 1. There is a significant overlap among these categories because of the multidimensional nature of the problem. Research projects that apply to two or more categories are grouped into the category most closely related to the original intent of the project. Figure 3 lists the specific areas of research chronologically and shows their approximate duration during the NMFS mortality-reduction program.

Net and Vessel Handling

Table 4 indicates that net configuration has a major influence on dolphin mortality. Chief among the various configuration problems is

prebackdown net collapse, which can be caused by strong currents, changes in wind direction and strength, major equipment malfunction, failure of the captain to orient the set properly with the wind, or any combination of these problems. Regardless of the cause of prebackdown net collapse, the outcome is the same; that is, a substantial portion of the captured dolphin school will be killed and the tuna may be lost as well. Because the fishery will, at times, involve setting despite adverse conditions and because equipment may occasionally fail, the development of a means to prevent net collapse rather than remove the causes was essential.

Speedboats to Prevent Net Collapse

Beginning in late 1972, experiments on the use of speedboats to prevent net collapse were initiated. Since most tuna seiners carried four or five speedboats for herding dolphins, the means for towing on the net were readily available. During the chartered cruises of the M/V *Trinidad* (1973), the M/V *John F. Kennedy* (1973), the M/V *South Pacific* (1974), and the M/V *Bold Contender* (1975), the methods and the practicability of using up to three speedboats to tow on the net to prevent net collapse under most conditions were proven[4,5].

Tests during commercial fishing operations showed that the temporary crew reduction on deck while speedboats were towing did not cause a marked increase in the duration of the set, especially when the alternative of dealing with large numbers of dead dolphins was considered. However, to avoid reducing the deck crew during a set, most captains became more attentive to their methods of setting in order to reduce the likelihood of net collapse. A substantial portion of the reduction in observed kill-per-set was due to increased awareness on the part of the captains. The 1976 regulations required at least two speedboats to be in the water during every set on dolphins and that they be crewed and prepared to tow on the net should it be necessary before the start of backdown. Since the need to tow on the net to prevent imminent collapse was infrequent if captains were careful, this regulation was considered a nuisance and was ignored by many captains.

Optimizing Set Orientation

While the use of speedboats was being developed, devices to provide more information to the captain on the direction of the current and the orientation of the set relative to the wind and current were examined. With this information, the captain could select the optimal set orientation to minimize the potential for net collapse. A current-direction indicator consisting of a roll of approximately 100 m of surveyor's tape with a weight on one end and a float on the other was tested on the cruises of the M/V *John F. Kennedy* (1973), the M/V *Trinidad* (1973), the M/V *J. M. Martinac* (1974), the M/V *South Pacific* (1974), and the M/V *Bold Contender* (1975).

Concurrently, a multibezel compass was devised that allowed the captain to set the bezels for wind and current direction (from the current-direction indicator) and to determine the direction in which to initiate the set that best balanced those forces on the net. The current indicators were found to be unreliable because they only indicated surface-current direction while it is the difference in magnitude and direction of surface and subsurface currents that affects the net.

The multibezel compass provided the correct information to properly orient a set. However, the business of orchestrating the chase and controlling the activities on board the seiners generally kept captains too busy to use this tool. Since the current indicators were not always reliable, and the multibezel compass only showed the correct orientation to the wind, which was available to the captain from direct observation, there was no need for the compass. This line of experimentation was therefore dropped.

Preventing Roll-ups

Most purse seine sets are not likely to result in a collapsed net if the net is retrieved without much delay. A common delay in purse seining is the roll-up in which the purse cable, leadline, and webbing become wrapped around one another, usually in both directions of rotation, such that they lock against each other. When a severe roll-up occurs, the net cannot be pursed until the roll-up is cleared. The delay can result in net collapse if speedboats are not used to hold the net open.

NMFS began studying the cause of roll-ups in late 1972 and discovered that roll-ups are caused by the purse cable rotating as tension is increased or decreased. Standard wire rope used for purselines is analogous to a long spring that, when stretched, creates torque along its length. When tension is applied, the cable rotates in one direction, and when tension is relieved, the cable rotates in the opposite direction. If, when setting the net, the leadline or webbing comes into contact with the rotating purse cable and is snagged, a roll-up results. Roll-ups occur occasionally on every vessel in the fleet.

In 1973, antitorque purselines were constructed and tested on chartered cruises of the M/V *John F. Kennedy* and the M/V *Trinidad*. These purselines were constructed of torque-balanced wire rope, which allows virtually no tension-induced rotation to occur because of the opposing lay of its major and minor component strands. The tests showed that the antitorque purseline worked. Beginning in 1974, NMFS supplied the cable to vessels that were experiencing a high frequency of roll-up sets. Roll-ups, however, still occurred on these vessels but less frequently. The fishermen also encountered a problem with the press fittings used to form eyes at the end of the cable. When the press fittings passed over the purse blocks they eventually cracked and required repair. A special splicing technique to form the eyes was developed. However, the fishermen did not completely accept this remedy, and by

[4]Everett, J., J. E. Powers, R. McNeely, J. M. Coe, and R. Butler. 1976. The use of speedboats in reducing incidental porpoise mortality in tuna purse seining. U.S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-76-35, La Jolla, Calif., 29 p.

[5]McNeely, R. L., and D. B. Holts. 1977. Methods of reducing porpoise mortality in the yellowfin purse seine fishery. U.S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-77-13, La Jolla, Calif., 19 p.

1976 most of the vessels that were experimenting with antitorque purselines replaced them with conventional purselines.

That roll-ups still occurred with the antitorque purseline indicates that the cable is not rotation free. The torque-balanced cable has a much longer, more open lay than conventional cable, and when passed over standard purse blocks under tension it has a tendency to flatten out. This "unlaying" of antitorque cable on the sheave of the purse blocks artifically induces torque (and rotation) into the purselines. To correct this problem, special purse blocks were designed with a 20-inch pitch diameter that were counterbalanced so the cable would always ride in the center of the sheave and not flatten out. A system of antitorque purseline and counterbalanced purse block was tested during three cruises aboard one of the more roll-up prone seiners. The results were inconclusive[6,7] and the research was terminated. To date, the antitorque system has not been further developed or incorporated into the fleet.

Quick Release Purse Rings

To remove and reattach purse rings easily during pursing has potential for increasing the speed with which the net can be retrieved when a malfunction occurs. A fisherman, Raphael Guillen, invented a snap link for this purpose in 1976. The NMFS tested this device during the chartered cruise of the M/V *Margaret L.* in 1977. The snap links were found to be useful in reducing delays in net retrieval and the device was recommended to the fleet.

Optimizing the Backdown-Channel Configuration

The most delicate and also most important net- and vessel-handling technique in a purse seine operation involving dolphins is backdown. A large part of the dolphin mortality occurs during backdown (Table 4). By the end of 1977, considerable progress had been made in solving the problem of prebackdown net collapse, and biologists had begun to understand the dynamic processes governing breakdown-related dolphin mortality.

A diving program was established, a model-net study program was initiated, and instruments for recording depth, depth/time relationships, net and vessel speed differentials, and relative changes in enclosed surface area were assembled. Cruises of the M/V *Queen Mary* in 1978 and the M/V *Maria C.J.* in 1979 and 1980 were designed to collect information on net behavior during breakdown. Observations from those cruises resulted in recommendations for an improved mid-net zipper design (Holts, 1980), more precise net tie-down locations on the net for optimal backdown-channel configuration, and instructions for determining causes and remedies for poor backdown performance (Coe et al., In press). This work also served to identify some previously unknown features of backdown dynamics.

Net-Depth Effects

With the development of improved methods for assessing the physical performance of a purse seine, efforts to quantify and demonstrate the positive effects of increased net depth were carried out. With bathykymographs and a systematic method for approximating net-enclosed surface area, an experiment was run aboard the M/V *Cabrillo* in 1979. For the experiment, the *Cabrillo's* net was deepened by two standard strips tapered at each end and inserted at the leadline. The average fishing depth of the net was increased by 17.3 m (9.4 fm) using six bales[8] of webbing. Net-enclosed surface area was increased by an average of 11.5 percent which gave the dolphins more room to move both before and during backdown. This also increased the time for the net to collapse. As a result of this experiment, specific performance data were collected to support the long-standing NMFS recommendation (footnote 5) that nets used on dolphin schools should be deepened whenever possible.

Miscellaneous Techniques

Many simple methods of employing standard vessel- and net-handling gear to minimize net configuration problems were recorded and shared with captains in the fleet. Most of these methods were obvious and effective but were not necessarily widely known. For example, in a normal set the captain has at his disposal the use of the net skiff, the bowthruster, and the main engine to prevent net collapse and to position the vessel in order to effect a smooth transition into backdown. Coe et al. (In press) discussed these techniques in detail.

Dolphin Handling Methods and Gear

While research on net- and vessel-handling techniques sought to prevent situations that directly endangered dolphins confined in the net, research on dolphin handling methods and gear sought ways to release dolphins efficiently from the net. Again, many of the effective methods for dolphin handling were practiced by the fishermen before this research program was begun, though many either were not widely used or were not being employed to their maximum effectiveness. Obvious examples are the backdown maneuver and the Medina Panel (see Glossary: Table 1).

Alternatives to Backdown

One of the earliest and most commonly suggested solutions to the tuna-porpoise problem was a gate built into the net that could be opened to allow the dolphins to swim away. A porpoise gate was built and tested aboard NMFS research vessels in 1970 and the M/V *Westport* and M/V *San Juan* in 1971. The gate (an inflatable/deflatable tube replacing a section of corkline) performed as designed. It sank rapidly to provide a controllable 15 m wide by 4.5 m deep opening. The dolphins, however, would not take advantage of the opening despite being herded with skiffs and a false corkline with evenly

[6]Coe, J. M., and D. A. Bratten. 1978. Cruise Report: M/V *Margaret L*, October 27-December 22, 1977. NMFS Southwest Fish. Cent., La Jolla, Calif. Unpubl. rep., 9 p.
[7]McLain, R. W., D. A. Bratten, and J. M. Coe. 1977. Cruise Report: M/V *Margaret L.*, May 19 to Sept. 11, 1977. NMFS Southwest Fish. Cent., La Jolla, Calif., Unpubl. rep., 8 p.

[8]100 meshes deep × 100 fathoms long, stretched mesh.

spaced drop lines. White noise (randomly generated sounds of equal energy) and killer-whale sounds were also used to herd the dolphins to the opening without success. These results illustrated a fundamental behavior of dolphins: The dolphins are more afraid of the net than of anything within it. To release them from the net requires some active process that literally pulls the net out from under them. Although this principle was recognized early on, several alternative methods for release were also considered in the early and mid 1970's.

Dual Purselines

The first alternative method was based on the hypothesis that early in a set there is a distinct vertical separation of tuna and dolphins (the dolphins at or near the surface and the tuna well beneath). It was proposed that a secondary purseline be installed at mid-depth, running the length of the net, that could be pulled at the same time as the standard purseline. Thus the pursed net would be divided into upper (dolphins) and lower (tuna) compartments (footnote 2). The corkline could then be opened with a zipper arrangement, and the dolphins either would swim out or be forced out by pulling the net from under them. A model net was built in mid-1972 to test the mechanics of this concept. However, further work on this was abandoned when underwater observations made aboard the M/V *Independence* in late 1972 showed that there was no consistent spatial or temporal separation of tuna from dolphins in the net.

Skimmer Net

In late 1972 the idea of using a lampara-type skimmer net was tested to see if the dolphins could be quickly gathered together and dumped over the corkline soon after pursing was completed. The M/V *Independence* was chartered for tests off southern California. The tests showed that the concept did not work because: 1) Most of the dolphins easily avoided the skimmer net, 2) dolphins that were herded to the corkline were trapped there and could not be easily released, and 3) speedboats did not have enough power to pull the skimmer net effectively.

The Dual Backdown

NMFS observations indicated that a number of dolphins were often left alive in the net after backdown. Afraid of losing the tuna, the captains discontinued backdown before all the dolphins were released. As a possible solution to this problem, a dual backdown system was conceived in 1973 and tested using model nets aboard a chartered salmon seiner and the tuna seiners M/V *John F. Kennedy* (May 1973) and M/V *Trinidad* (October 1973).

The dual backdown principle involved the development of a net configuration with two backdown channels of approximately equal size adjacent to each other, with a controllable passage between them. Tuna normally cruise up and back in the channel during backdown, so that they might be directed through a passage into the second channel and held there without risk of escape while all of the dolphins were released from the first channel. In practice, the dual channels were difficult to form without collapsing them, and the tuna were never effectively transferred to the second channel. The idea was therefore abandoned as impractical.

Small Mesh Safety Panels

Harold Medina observed that the standard mesh size (4¼-inch stretched mesh) for tuna seines was much too large to prevent the entanglement of dolphin snouts and flippers. In 1970 he installed a strip of 2-inch stretched mesh webbing at the backdown apex of his net and noted good results. Data collected by NMFS observers in 1971 and 1972 (footnote 2) from vessels with and without the 2-inch panel confirmed Medina's results, showing lower mortality rates for vessels with the smaller mesh panel. A great deal of subsequent industry and NMFS research effort from 1972 through 1977 went into extending Medina's concept and developing better safety panels for the backdown channel, since backdown literally forces the dolphins into contact with the net while effecting their release.

The single-strip, 2-inch mesh Medina Panel was rapidly incorporated into nets of the U.S. fleet, and by 1974 nearly all nets had it. Some captains chose to use two strips of 2-inch mesh of varying lengths for their backdown apex. In 1973 experts questioned whether the 2-inch mesh was the ideal size to prevent entanglement. NMFS conducted a series of experiments to determine the mesh size that was most effective in preventing entanglement of beaks and flippers (Barham et al., 1977) and found that 1¼-inch stretched mesh was most appropriate. Accumulated observations of where dolphins became entangled in the channel were used to establish NMFS specifications for the placement of 1¼-inch mesh safety panels, which replaced the 2-inch mesh Medina Panels.

In 1973, NMFS designed and built a large volume net that was 17 strips deep. The net's backdown area was protected by a safety panel that was made up of three standard-depth strips of 1½-inch stretched mesh webbing. The large-volume net was tested on cruises in late 1973 (M/V *John F. Kennedy*) and 1975 (M/V *South Pacific*) with encouraging results. Further refinements in safety-panel design were investigated during the 1976 fishing season, when 20 volunteer vessels were equipped with 1¼-inch mesh safety panels either with or without an apron-chute appendage (see below). The kill rate for these vessels were markedly lower than those for vessels with a regular net[9]. In 1977, all vessels were required to install two strips, each 340 meshes deep, of 1¼-inch mesh webbing 180 fathoms in length, starting within the second outermost bow-corkline bunch and running sternward. The industry accepted this modification as a progressive change, and, although there were some webbing supply problems, most vessels were in compliance by the end of 1977. The reduction in kill rate from 14 animals per set in 1976 to 3 animals per set in 1977

[9]Coe, J. M., and J. DeBeer. 1977. Results of the 1976 twenty-vessel test of two fine mesh systems to reduce incidental porpoise mortality in tuna purse seining. Unpubl. manuscr. on file at NMFS Southwest Fish. Cent., La Jolla, Calif., 75 p.

(Table 3) was, in our view, largely the result of this change in net design.

Preventing Backdown Canopies

While collecting data on the backdown procedure, biologists observed that net canopies made dolphin release more difficult and contributed to dolphin mortality. Surface net canopies entrap dolphins and prevent them from drifting or swimming to the apex of the backdown channel to be released from the net. Because of the canopies, up to 20 animals were occasionally left in the net after backdown.

To eliminate surface canopies, the slack webbing near the surface of the backdown channel needs to be redistributed to optimize the amount of net in the water. In the fall of 1974 a tapered, trapezoidally-shaped section of 2-inch mesh webbing called the "apron" was installed in the net of the chartered vessel M/V *South Pacific*. The apron was inserted between the corkline and the upper edge of the safety panel, with its short side up, and centered at the backdown apex. This installation required tiedown to be at the same place for each set. On this cruise, the apron was tested and judged effective in reducing surface canopies in the backdown channel.

A number of vessels volunteered to test aprons during the 1975 fishing season and had mixed results and opinions[10]. A similar 1¼-inch mesh apron with a more sharply tapered extension piece mounted at its top center (called the "chute") was installed with a 1¼-inch mesh safety panel in the net of the M/V *Bold Contender* in the fall of 1975. Results with this net design were extremely encouraging, producing kill rates well below the 1975 fleet average. The "Bold Contender System," as the apron-chute complex came to be known, was tested on 10 vessels and compared with 10 vessels using only the two-strip, 1¼-inch mesh safety panel. This test ran the entire year of 1976. When the results were analyzed, both systems were found to produce significantly lower kill rates than did conventional gear, with the Bold Contender System slightly better than the safety panel alone (footnote 9 and SWFC[11]).

During this 20-vessel test, some simple problems in handling the Bold Contender System were identified. To deal with these problems, the chute was trimmed down so that the remaining "super apron" was a long, low triangle with its apex coinciding with the desired backdown channel apex. This modification seemed to eliminate the handling problems. The net design was adopted voluntarily by a number of vessels in the fleet, based on the results of the fall 1976 chartered cruise of the M/V *Elizabeth C. J.* The super apron became mandatory by regulation beginning in 1978.

The Backdown Zipper System

At the same time that the apron was developed, biologists designed a method to reduce the risk of loss of tuna during backdown. A series of 3-inch steel rings were lashed to the net in the backdown area in a way that allowed a rope to be strung through them. The rope, when pulled, pinched the channel shut near the apex. The idea was to back down until all the dolphins were at the apex and the tuna had moved toward the boat, and then to pull this backdown zipper separating the dolphins and tuna.

During the charters of the M/V *South Pacific* (1974) and the M/V *Bold Contender* (1975), the mechanics of the zipper proved sound, but the dolphins were not always on the apex side. In addition, the zipping action caused the apex end of the backdown channel to become shallow and to collapse. The animals became entrapped and were not easily released. The zipper idea was therefore rejected. As an alternative, the apron was refined so that it produced a sloping apex floor that tended to turn the fish away from the release area and thereby reduce the loss of fish during backdown.

Releasing Dolphins by Hand

In considering ways to increase the number of sets with no dolphins killed, it was recognized that backdown alone rarely got every animal out of the net and that some efficient form of hand-release of individual animals was needed. Several rescue techniques for hand-release were already in use in the fleet prior to NMFS involvement. These were: 1) Rescuers in speedboats released animals at the surface and next to the corkline, 2) rescuers dove and swam in the net to catch and release both entangled and free-swimming dolphins, and 3) from the speedboats and the net skiff, rescuers used gaffs to guide dolphins over the corkline. Rescue from speedboats was inefficient because of the rescuers' limited reach and lack of mobility. Swimming in the net was fairly efficient, depending on the skills of the rescuer, but dangerous because of potential shark attacks and rescuer entanglement in the net. Gaff wounds are potentially fatal to dolphins, depending on the severity and location of the punctures.

During a cruise aboard the M/V *Gina Karen* in 1974, it was noted that having two persons aboard a speedboad stationed at the backdown apex during backdown increased efficiency of hand-release of dolphins. Analyses of data from the fleet supported this conclusion, and the practice was made a requirement in 1975. During the charter cruises of the M/V *Bold Contender,* the M/V *Elizabeth C. J.,* and the M/V *Margaret L.,* NMFS tested the feasibility of using an inflatable one- or two-man raft as a platform from which rescue could be performed. It was found that, with practice, a single man in the raft could easily maneuver the raft and, with the aid of a face mask and snorkel, rescue dolphins more efficiently than any other method. Furthermore, the raft provided some protection for the rescuer from shark attacks, while the face mask allowed him to see clearly whether there were sharks, billfish, stingrays, or jellyfish in the area where he was working. This raft-

[10]Coe, J. M. 1976. The effectiveness of the porpoise apron in improving the backdown procedure. U.S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-76-38, La Jolla, Calif., 17 p.

[11]SWFC. 1972. Unpubl. manuscr. by SWFC Staff on file at Southwest Fish. Cent., La Jolla, Calif.

rescue technique has been in use by the fleet since 1976. Since hand-release in any form is not without some risk, the regulation is written so that raft use is at the captain's discretion.

While the raft-rescue technique was being tested on the M/V *Bold Contender* and M/V *Elizabeth C. J.*, some dolphins were observed to drop out of the school at the surface and come to rest passively on the floor of the backdown channel for a few minutes before rejoining the school. Without a mask and snorkel, the rescuers were not able to see these passive animals. The animals the rescuers did see were presumed dead. Passive behavior (Coe and Stuntz, 1980) was largely responsible for the unexpected appearance of live dolphins in the net after what had seemed to be a completely successful backdown with all dolphins released. The raft rescuer with a mask and snorkel can see the passive dolphins, signal the captain to continue backdown, and rescue the dolphins as they come to the surface. A regulation requiring the raft rescuer to wear a mask and snorkel also required backdown to continue until all live dolphins were released from the net. We believe that this regulation has contributed to the increased frequency of zero-kill sets after 1976 (Table 3) and the overall reduction in dolphin mortality.

Regulations in 1976 made the use of gaffs or other sharp-pointed instruments on dolphins illegal. When direct hand-release was not feasible (e.g., during sacking-up, after backdown, in the presence of sharks) a long-handled instrument (shepherd crook) for moving and controlling dolphins was needed and NMFS designed, built and distributed a number of different types of shepherd's crooks between 1975 and 1977. Results and opinions varied considerably among the users, but it was clear that in many circumstances the crooks could be effective and the degree of effectiveness depended on the user's effort. Many vessels have carried and made use of the devices.

The Apex Flapper

Behavioral observations made during the development of the raft rescue technique led to studies on altering the structure of the backdown apex to make it easier for the dolphins to leave the net. During backdown, many dolphins come into contact with the net just below the corkline and either swim back into the channel or lie against the webbing and are carried with it. Also, when tuna approach the backdown apex they see the webbing and corkline and usually turn back into the net, even though the corkline may be 3 or 4 feet underwater. It was reasoned that if the apex could be made semipermeable to dolphins and still present a visual barrier to the tuna, a more efficient backdown might result.

The initial and only attempt to design a differentially permeable apex produced the apex flapper system, which consisted of overlapping trapezoidal pieces of 1¼-inch mesh of increasing height placed above the corkline and centered at the backdown apex. A flat spot of about 20 fathoms was cut at the top of the apron (at the backdown apex), most of the floats were removed from the corkline, and the flappers, with floats attached at the top and middle, were laced in along the apex flat spot. This modified apron was tested on the M/V *Margaret L.* in the fall of 1977. Tests showed that too much flotation was left at the corkline, so the flappers tended to float on the surface inhibiting release and rescue at all but the highest backdown speeds. The merits of the apex flapper concept were never fully assessed and the method has not come into use.

The Downhaul Gate

Aboard the first cruise of the dedicated vessel M/V *Queen Mary* in 1978 (DeBeer et al.[12]), a simple system of downhauls in the half-net area that could be adjusted in length to cause the corkline to sink during pursing was rigged for testing. The intent was to create an opening through which dolphins could be driven before the purse rings were brought on board using the downward force on the corkline exerted by the purse winch. Before the test could be conducted, however, the downhaul ropes became tangled in the corkline during setting, and had to be removed.

Other Modifications

A number of additional minor dolphin-rescue modifications pursued during the decade deserve brief mention. During the chartered cruises of the M/V *J. M. Martinac* (1974) and the M/V *South Pacific* (1974), the effectiveness of closing the hand-hold openings and corkline hangings to prevent entry of dolphin beaks and flippers was shown. Regulations to implement this finding were enacted in 1976. Experiments to determine the efficiency of large safety panels and aprons on the smaller vessels in the fleet were run on the M/V *Eastern Pacific* (1975) and the M/V *Marla Marie* (1977) with mixed results.

Evaluating Integrated Net Designs

The means for testing and demonstrating the gear ideas developed by the project ordinarily consisted of simple vessel cruises employing their own net with a specific modification. The high cost of dedicated vessel time and net construction and maintenance prohibited the integration and testing of broad combinations of experimental gear. However, three methods were developed to evaluate multiobjective gear designs: 1) A full-sized net, 2) scale-model nets, and 3) an interactive computer simulation of net behavior.

Large-Volume Net

In the summer of 1973, this prototype net was designed to demonstrate a number of advanced dolphin-saving features as well as advanced fishing

[12]DeBeer, J., F. Awbrey, D. Holts, and P. Patterson. 1978. Research related to the tuna-porpoise problem: Summary of research results from the first cruise of the dedicated vessel, January 26 to March 16, 1978. U.S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-78-14, La Jolla, Calif., 27 p.

technology. Its decreased length:depth ratio and sharply tapered ends increased the enclosed surface area (and volume) when pursed, reducing the probability of net collapse. It was the first net to have three strips of dolphin-safety panel of less than 2-inch mesh (today's nets with aprons effectively have 3⅓-strip safety panels of 1¼-inch mesh). It was also the first net to have handholds and corkline hangings laced shut in the backdown area to prevent entanglement. Lighter than normal twine was employed in the body of the net, which saved material costs and let the net sink and be pursed more rapidly (an idea that has recently been employed by the fleet). Its depth of 17 strips of webbing was 5 or 6 strips deeper than most nets in the fleet at that time (today 15- or 16-strip nets are quite common). Its advanced designs have only recently gained wide acceptance. By 1975 the cost of maintenance and repair of this net was too high and the project was transferred to another Federal agency.

Scale Models

Two scaled-down model nets were built early in the program to study radical changes in fishing procedures and net designs. The first model was a 1:25 scale model of a nine-strip deep net which had a midnet purse line running the entire length. It was used to test the feasibility of double pursing to separate the tuna from the dolphins. These tests showed the concept to be unpractical, saving considerable time and resources in the early period of the program.

A second 1:50 scale model of a newly designed purse seine was constructed in the spring of 1973. This model featured 1) 17 strips to provide greater surface area thus preventing net collapse, and 2) tapered ends to reduce excess webbing and attendant gear malfunctions. This model showed sufficient promise and a full-sized, 17 strip, purse seine (the Large-Volume Net) was built in the fall of that year.

These early tests provided valuable information on purse seine dynamics and were useful in focusing research effort and resources on specific problem areas. They were again used in 1980 (Holts and Coe, 1982) to study the dynamics of both normal and modified backdown procedures as well as various related gear malfunctions.

Computer Simulation Model

There are two principal methods of determining net behavior: Experimental and analytical. The experimental method has the overwhelming advantage of producing tangible and irrefutable results. The disadvantages of the method are numerous: The expense of chartering fishing vessels is great, ocean parameters cannot be controlled and are difficult to measure, and modifying nets is costly.

In direct opposition, the analytical method has the disadvantage that the results are not real and may be challenged. This disadvantage can be eliminated by comparing the results of analysis with experimental measurements. If the analysis is verified by this comparison, the advantages of the second method are realized: Low cost and control of the ocean and net parameters. The key to obtaining these advantages is experimental verification.

From 1978 to 1981 a substantial portion of the funds for the mortality reduction project was spent to research and develop a computer-based, interactive numerical simulation of purse seine behavior and to establish field measurements with which to verify the results of the simulation program. Basic performance parameters such as sinking rates, pursing speed and tension, enclosed area and volume, setting speed, retrieval speed and backdown forces, and net skiff towing force were measured on the dedicated vessel (1978) and charters of the M/V *Maria C. J.* (1979 and 1980).

The computer simulation was developed in three phases under contract and was nearing completion in the fall of 1981. The simulation program was based on a system of differential equations which describe the motion of the net to be simulated. The user defines a sequence of external events (water currents, setting, pursing, etc.) affecting the motion which is to be simulated. The product of a simulation consists of a binary file for graphics display. Ultimately, the simulation was intended to be a broadly flexible tool for computer aided design (CAD) for a variety of fishing systems. This flexibility and accuracy were essential for cost-effective development of fishing systems directed to Phase-I goals. This program was terminated before benchmark runs could be carried out and simulation limits verified. Although the model was not used to solve fishing gear problems, it was used to simulate towed cables (Delmer et al., 1983) and changing and breaking cable systems (Stephens et al., 1982).

Behavioral Research

Throughout the decade, researchers have been trying to identify a key behavioral response by either the dolphins or the tuna that could be used to temporarily break the tuna-porpoise bond. Investigations, therefore, concentrated on mechanisms that could release dolphins from conventional purse seine nets (i.e., Phase-I work) and which might also serve as a basis for the development of alternate fishing systems not involving the capture of dolphin schools (Phase-II).

In their search to find ways to direct or elicit a predictable response (movement in a desired direction), researchers experimented with testing a wide range of acoustical signals on captured dolphins. Killer whale vocalizations to white noise and sounds of dolphins escaping were some of the signals tested. No underwater sound presented to captured dolphins has produced a response potentially useful in improving release efficiency. The first work was done in 1970 on the R/V *Miss Behavior* and the latest and most sophisticated work was done on the dedicated vessel,

Table 5.—Major malfunction categories showing frequency of occurence, severity in terms of percent malfunction-related mortality, and average loss of time for each of the 4 years, 1977-80.

Malfunction	1977 Sets f (%)	1977 Kill %	1977 Delay min.	1978 Sets f (%)	1978 Kill %	1978 Delay min.	1979 Sets f (%)	1979 Kill %	1979 Delay min.	1980 Sets f (%)	1980 Kill %	1980 Delay min.
Speedboats	120 (15)	9.1	1.0	78 (21)	2.1	1.2	82 (30)	13.3	1.4	85 (32)	0	8.0
Roll-up	151 (18)	12.3	34.0	59 (15)	11.6	46.7	39 (14)	16.9	53.2	22 (8)	13	57.2
Net tangled in rings	129 (16)	12.8	16.1	42 (11)	28.7	19.3	31 (12)	4.6	15.2	29 (11)	34	26.5
Purse cable	94 (11)	12.5	17.9	27 (7)	15.3	11.9	22 (8)	23.7	16.3	12 (5)	7	22.4
Hydraulic problems	73 (9)	5.0	22.3	44 (12)	4.6	27.7	17 (6)	4.7	18.4	24 (9)	3	26.2
Bow bunches	41 (5)	5.1	5.8	37 (10)	2.0	15.9	22 (8)	5.6	14.9	14 (6)	1	7.7
Skiff	63 (8)	18.1	23.1	35 (9)	7.6	16.3	29 (11)	21.1	17.7	17 (6)	8	13.7
Winch and stripper				12 (3)	1.8	17.8	6 (2)	2.7	41.7	0 (0)	0	0
Other	144 (18)	22.5	20.3	44 (12)	26.1	11.9	23 (9)	7.4	15.8	60 (23)	34	21.3

M/V *Queen Mary* in 1978[12, 13].

Visual stimuli were also tested briefly on a cruise of the M/V *Margaret L.* (fall 1977) and on the dedicated vessel. A bubble screen, created by scattering chunks of dry ice across the backdown channel, was tested in several sets of the M/V *Margaret L.* The bubble screen did not produce a clear, consistent response by the dolphins. Underwater strobe lights and underwater magnesium flares were tested on the M/V *Queen Mary* cruises, both day and night, before and during backdown. These tests also showed that dolphins do not respond to these visual stimuli in any predictable way.

Under contract to NMFS, researchers at the University of Hawaii developed various concentrations of natural chemical extracts of prey species and organic debris to test the response of captured yellowfin tuna to olfactory stimuli[14]. The researchers were able to elicit strong feeding responses in laboratory tuna with these extracts. They hypothesized that by presenting the extract that evoked the strongest response to tuna in the net they could be held stationary while the net was opened to release the dolphins. In field tests aboard the M/V *Queen Mary* in the summer of 1978, these olfactory lures did not produce a strong enough response by the tuna to warrant continuing the investigation. This contract research was ended in 1979.

Other Factors and Services Affecting Dolphin Mortality

Condition and Proper Use of Equipment

Much effort was expended on developing methods to alleviate many of the direct causes of mortality, but little had been done to address one of the more important indirect causes—malfunctions of machinery, gear, or procedures. These malfunctions were classified beginning in 1977 according to their relative contributions to dolphin mortality so that specific research areas could be identified (Table 5). Using these data, general recommendations for reducing rates and severity of some malfunctions have been prepared (Coe et al., In Press).

Operator Judgment

The captain's decisions are the most important factors influencing the outcome of tuna vessel operations. The level of experience and the amount of information he possesses help him analyze circumstances and determine the best course of action. Any application of advanced technology or refinement in fishing procedures to reduce dolphin mortality will be decided by the vessel captain. The captain must either believe in the usefulness of changes or be required to incorporate them by law. The successful transfer of technology and information is a major key to the reduction of dolphin mortality.

Of the many methods that have been employed, the most effective one is a combination of the regulatory observer program and the enforcement regime. Prior to the existence of regulations governing gear and procedures (before 1976), skipper workshops were held and informal waterfront contacts were frequent while searching for volunteer vessels and captains to carry research observers. With the establishment of the mandatory observer program and vessel operator certification requirements, skipper training sessions (with mandatory attendance) were held. The regulated gear and procedures as well as the latest developments in mortality-reduction technology were presented at these sessions. "Marketing" methods for this information were not researched.

Extension Services

In 1977, NMFS established an extension service primarily to assist captains in the proper installation and

[13]Awbrey, F. T., T. Duffy, W. E. Evans, C. S. Johnson, W. Parks, and J. DeBeer. 1979. Summary of research results from the first leg of the third cruise of the dedicated vessel, June 22 to July 15, 1978. U.S. Dep. Commer., NOAA, NMFS, SWFC, Admin. Rep. LJ-79-11, La Jolla, Calif., 29 p.

[14]Ikehara, W. N., and J. E. Bardach. 1981. Chemosensory attracting and guiding of yellowfin tuna, *Thunnus albacares*. NOAA Contract 03-7-208-35268. U.S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-81-07C, La Jolla, Calif., 42 p.

alignment of aprons, and also to disseminate information on other mortality-reduction techniques. The extension group monitored observer reports of incoming vessels for high kill rates and gear problems, and then met with the captains to discuss the problems on an informal basis. This work was coordinated with the NMFS Southwest Regional Office, the industry-sponsored Porpoise Rescue Foundation, and the Expert Skipper's Panel. The Expert Skipper's Panel, working directly with the extension group, has been very successful in the transfer of this information to the fleet by making captains aware of specific techniques and procedures for reducing dolphin mortality.

Discussion

The remarkable reduction of annual estimated dolphin mortality in the U.S. tuna fleet from 315,000 animals in 1970 to 16,900 animals in 1980 without any substantial changes in the basic fishing methods reflects two things. First, in 1970 there was tremendous potential for improvement in the standard tuna purse seine technology for release of dolphins without affecting fishing success. Second, the improvements were adopted by the fleet quite rapidly. The improvements, whether required by law or used voluntarily, appear to have had very little, if any, negative impact on fishing efficiency. Reductions in dolphin kill of this magnitude (from 70 animals per set in 1970 to about 3 per set in 1980) have shortened the average set duration. The improved methods and gear have been based on compatibility with existing purse seining technology, and as such have also been employed by many foreign tuna boats.

That more than a decade passed with the concentration in mortality-reduction research on the Phase-I objectives is not surprising when one considers the severity of the problem in the beginning and the fact that only one or two major field experiments aboard chartered vessels could be reasonably executed in any given fishing year. Background information and experience had to be developed before experiments could be devised, and an incredibly broad range of ideas for solutions had to be evaluated. The diversity within the fleet coupled with limited research funds made designing experiments to meet stringent statistical requirements impossible. Even when economically and logistically acceptable gear and methods were devised, their introduction into practice was slow due to the traditional nature of the evolution of fishing systems and the difficulty in communicating with operators who were at sea 200-300 days a year.

The enactment of gear and procedural regulations by NMFS, coupled with the observer program, was instrumental in helping the fleet lower its kill rates in the shortest possible time. When carrying an observer aboard his vessel, a captain was under considerable pressure to use every technique at his disposal to minimize kill, since his performance was extrapolated to the entire fleet to monitor the kill quota (beginning in 1976). The frequency of observer trips (about 1 per year per vessel) and the resulting visibility of performance has served to create a competitive atmosphere among captains, raising their motivation and competence in dolphin release to very high levels.

As long as there is a management-oriented "porpoise observer program" and the annual kill quotas are reasonably close to levels attainable by the U.S. tuna fleet using present methods, there is every reason to expect kill rates to remain relatively unchanged. Kill rates may increase over time, however, if the extension services to the fleet are not continued on a high level. Kill rates cannot be expected to decrease significantly in the absence of technological improvements, since the fleet appears to have incorporated successfully nearly all mortality-reducing measures that are presently available. Mistakes are made, however, and accidents happen; occasional high-kill sets still occur. This is to be expected since the environment, dolphin behavior, and equipment malfunctions are difficult for vessel captains to anticipate or control.

There is, however, the potential for developing fishing technology to further reduce the present dolphin kill rates. Investigations into the backdown operation had led to a basic understanding of the dynamics involved. Further investigations aimed at optimizing the configuration of the backdown channel and reducing the number and severity of canopies and premature net collapses hold a high degree of success. The idea of a dolphin-permeable backdown apex was never fully investigated and also deserves much more attention.

Information gathered on net designs from other purse seine fisheries where roll-ups do not occur would be useful in the elimination of that plaguing problem. The potential roll of model nets and computerized simulation models to investigate innovative net designs, alternative mesh configurations, and solutions to persistent mortality-related problems is great. These models also have the clear advantage of being less costly both in terms of time and money. Continued high-level support of the extension services to gather, analyze, and disseminate pertinent information on gear and machinery maintenance problems, dolphin rescue techniques, and operational procedures is very important. The timely transfer of their results and recommendations to the tuna purse seine fishery at large can be achieved through existing industry sponsored groups such as the Expert Skipper's Panel.

The results of implementing these ideas would bear directly on the kill rates of the present purse seine fleet. If reducing the total number of sets on dolphins can be considered as a partial solution to the problem, then a number of other research and development projects might be undertaken to increase the harvest efficiency for tunas not associated with dolphins.

Development of alternative fishing systems which do not entail the cap-

ture of dolphins when harvesting the associated yellowfin tuna, the full realization of the Phase-II goal, is a distant prospect. To begin addressing the idea will require a research program that is basic and broadly based, to fully delineate the nature of the tuna-dolphin bond, and to then develop a means to temporarily break or alter that bond. If these steps are satisfactorily completed, a modified fishing system to capture the tuna will then have to be devised. Such a system, of course, would have to be economically equal or superior to the present system and would have to be compatible with present-day vessel design, at least in the short run. Aside from the systematic rejection of a number of proposed solutions to this problem, very little progress has been made toward a realistic solution for the elimination of the incidental involvement of marine mammals in tuna purse seining.

Some very basic lessons have been learned in the course of this research. These lessons are generally applicable to most fishing technology problems. First, relative to industry relations:

1) In order to successfully research gear-technology problems in fisheries, the cooperation and confidence of the fishermen is essential.

2) Social systems and tradition are very important factors in the success or failure of technology transfer in fisheries.

3) Much of what fisheries technologists need to know to solve a problem is usually already known by someone in the fishery.

4) The fishing community will resist intervention regardless of how benign or progressive its intent.

Second, with regard to the conduct of applied research on fishing technology problems:

1) Enough vessel time is rarely available to adequately test and modify experimental gear and procedures.

2) In a fully operating commercial fishery, organizing and fielding a well-designed experiment is extremely difficult because a large number of variables cannot be controlled.

3) Modification of the physical performance of fishing gear is often complicated by the lack of fixed points or fulcrums from which to exert desired forces.

4) With experimental vessel time at a premium, the probability of unfavorable experimental outcomes should be minimized through extensive shoreside investigations and preparations.

5) The amount of useful information which can be derived from observations and measurements taken only at the surface is limited. Remote sensing equipment and diving capabilities are essential for complete assessment of most fishing technology problems.

6) Fishing technology tailored to accommodate the natural behavior of the animals involved has a high probability of success.

Acknowledgments

The research and this report were made possible by many more individuals than can ever be properly acknowledged. W. F. Perrin, E. G. Barham, W. W. Fox, Jr., J. T. Everett, and, especially, R. L. McNeely were the individuals in NMFS responsible for the initiation, support, and direction of the research. On the industry side, special thanks go to F. G. Alverson, A. Felando, L. Brito, D. Burney, N. Mendes (now with NMFS), M. Zolezzi, J. DeBeer, C. Peters, and many other representatives of the industry who recognized the need for this research.

Many captains over the years have participated in and advised this program. Consistent support and valuable information were received from Captains G. Sousa, L. Castagnola, A. Castagnola, J. Zolezzi, V. Guarassi, J. Scafidi, J. Medina, Jr., J. Melussi, M. Silva, J. Gonsalves, M. Jorge, and J. Jorge. We thank particularly R. Silva, who captained the Dedicated Vessel M/V *Queen Mary*.

Reviews of this paper were received from W. Perrin, T. Smith, G. Stauffer, G. Sakagawa, R. Lasker, I. Barrett, and J. Michalski. Figures for the paper were prepared by H. Orr.

Literature Cited

Allen, R. L., and M. D. Goldsmith. 1982. Dolphin mortality in the eastern tropical Pacific incidental to purse seining for yellowfin tuna, 1980. Rep. Int. Whaling Comm. 32:419-421.

Barham, E. G., W. K. Taguchi, and S. B. Reilly. 1977. Porpoise rescue methods in the yellowfin purse seine fishery and the importance of Medina panel mesh size. Mar. Fish. Rev. 39(5):1-10.

Coe, J. M., D. B. Holts, and R. W. Butler. In press, Guidelines for reducing porpoise mortality in tuna purse seining. U.S. Dep. Commer., NOAA Tech. Rep. NMFS.

_____, and G. Sousa. 1972. Removing porpoise from a tuna purse seine. Mar. Fish. Rev. 34(11-12):15-19.

_____, and W. E. Stuntz. 1980. Passive behavior by the spotted dolphin, *Stenella attenuata*, in tuna purse seine nets. Fish. Bull., U.S. 78:535-537.

Delmer, T. N., R. C. Stephens, and J. M. Coe. 1983. Numerical simulation of towed cables. Ocean Engineering 10(2):119-132.

Federal Register. 1977. Title 50, Wildlife and Fisheries, Chapter II. Part 216. Regulations governing the taking and importing of marine mammals. 42(247):64548-645650.

Holts, D. B. 1980. The mid-net zipper ridge, a possible cause of unobserved porpoise mortality, U.S. Dep. Commer., NOAA Tech. Memo. NMFS-TM-SWFC-3, 3 p.

_____, and J. M. Coe. 1982. Preliminary studies of model purse seine nets. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFC-25, 19 p.

McNeeley, R. L. 1961. The purse seine revolution in tuna fishing. Pac. Fisherman 59(7):27-58.

NMFS. 1975. Draft environmental impact statement: Promulgation of rules and proposed issuance of permits to commercial fishermen allowing the taking of marine mammals in the course of normal commercial fishing operations. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Sept. 1975, 77 p.

Perrin, W. F. 1969. Using porpoise to catch tuna. World Fishing 18(6):42-45.

_____. 1970. The problem of porpoise mortality in the U.S. tropical tuna fishery [Abstr.], p. 45-48. *In* Proceedings of the Sixth Annual Conference on Biological Sonar and Diving Mammals, Oct. 17-18, 1969. Stanford Res. Inst., Menlo Park, Calif.

Stephens, T. C., T. N. Delmer, and J. M. Coe, 1982. Simulation of changing and breaking cable and net structures, p. 773-777. *In* Proc. Oceans 82 Conf. Sept. 20-22, 1982. Mar. Technol. Soc., Wash., D.C.

Bibliography[15]

Awbrey, F. T., T. Duffy, W. E. Evans, C. S. Johnson, W. Parks, and J. DeBeer. 1979. Summary of research results from the first leg of the third cruise of the dedicated vessel, June 22 to July 15, 1978. SWFC Admin. Rep. LJ-79-11, 29 p.

Barham, E. G. 1974. The porpoise-tuna problem: Review of research progress. SWFC Admin. Rep. LJ-74-4, 164 p.

Beltestad, A. K. 1980. Purse seines with hexagonal mesh. Norw. Fish. Technol. Res. Inst. Rep. 661.5-4-11, 45 p. (Engl. Transl. as SWFC Admin. Rep. LJ-81-12, 60 p.)

Bratten, D. A., W. Ikehara, K. Pryor, P. Vergne, and J. DeBeer. 1979. Summary of research results from the second leg of the third cruise of the dedicated vessel. July 20 to August 18, 1978. SWFC Admin. Rep. LJ-79-13, 39 p.

Butler, R. W. 1980. Cruise report: M/V *Cabrillo*, May 19 to July 19, 1979, 6 p.

_____. 1980. Cruise report: M/V *Cabrillo*, August 18 to October 7, 1979, 13 p.

_____, and T. C. Foster. 1981. Cruise report: M/V *Maria C.J.*, September 22 to December 28, 1980, 25 p.

Coe, J. M., and P. J. Vergne. 1977. Cruise report: M/V *Elizabeth C.J.*, October 7 to December 9, 1976, 9 p.

_____, and _____. Modified tuna purse seine net achieves record low porpoise kill rate. Mar. Fish. Rev. 39(6):1-4.

_____, J. G. Jennings, C. B. Peters, and J. DeBeer. 1979. Research related to the tuna-porpoise problem: Summary of research results from the second cruise of the dedicated vessel, April 17 to June 5, 1978. SWFC Admin. Rep. LJ-79-6, 59 p.

DeBeer, J., F. Awbrey, D. Holts, and P. Patterson. 1978. Research related to the tuna-porpoise problem: Summary of research results from the first cruise of the dedicated vessel, January 26 to March 16, 1978. SWFC Admin. Rep. LJ-78-14, 27 p.

Delmer, T. N., and T. C. Stephens. 1979. Numerical simulation of net fishing, Part 1: Physical and numerical foundations. Science Applications, Inc., Contract NASO-78-0266. *In* SWFC Admin. Rep. LJ-81-13C, 122 p.

Evans, W. E. 1972. Cruise report: M/V *Queen Mary*, November 16 to December 17, 1971, 5 p.

Everett, J., J. M. Coe, and J. E. Powers. 1976. Porpoise/tuna interaction technology-based problems and solutions. SWFC Admin. Rep. LJ-76-33, 16 p.

Fabrick, A. J., and L. Faverty. 1974. Final report. Analysis of porpoise kill data, National Oceanic and Atmospheric Administration Contract 03-4-208-301, Southwest Fisheries Center, La Jolla, Calif., 53 p.

Fish, J. F., and G. E. Lingle. 1973. Acoustic research aimed at reducing porpoise mortality in the tuna fishery. Submitted to National Marine Fisheries Service, 8 p.

Fox, W. W., Jr. 1978. Tuna/dolphin program: Five years of progress. Oceans 3:57-59. (Also publ. in NMFS Tuna Newsl. 58 (May-June 1978), 6 p.

Gonsalves, J. T. 1977. Improved method and device to prevent porpoise mortality. Application of polyvinyl panels to purse seine nets. U.S. Dep. Commer., Natl. Tech. Inf. Serv. Rep. PB 275088, 36 p.

Green, R. E., W. F. Perrin, and B. P. Petrich. 1971. The American tuna purse seine fishery, p. 182-194. *In* Hilmar Kristjonsson (editor), Modern fishing gear of the world, Vol. 3. Fish. News (Books) Ltd. Lond.

Holts, D. B. 1974. Cruise report: M/V *John F. Kennedy*, November 10 to December 15, 1973, 19 p.

_____. 1976. Cruise report: R/V *David Starr Jordan*, October 5 to November 18, 1975, 7 p.

_____. 1977. The super apron system, construction and installation. SWFC Admin. Rep. LJ-77-30, 12 p.

_____, and M. Deerman. 1978. Cruise report: M/V *Marietta*, September 25 to December 7, 1978, 5 p.

_____, R. McLain, F. G. Alverson, and J. DeBeer. 1979. Summary of research results from the fifth cruise of the dedicated vessel, November 11 to December 9, 1978. SWFC Admin. Rep. LJ-79-20, 60 p.

Jurkovich, J. E., 1975. Cruise Report: M/V *Eastern Pacific*, September 29 to December 6, 1975, 6 p.

_____, and E. G. Barham. 1974. Cruise Report: M/V *South Pacific*, June 25 to September 1, 1974, 4 p.

McNeely, R. L. 1973. Cruise report: M/V *John F. Kennedy*, May 23 to June 5, 1973, 14 p.

_____. 1973. Cruise report: M/V *Trinidad*, October 16 to November 11, 1973, 7 p.

_____. 1973. Cruise report: M/V *Independence*, December 11 to December 17, 1972, 10 p.

_____, and D. B. Holts. 1974. Cruise report: M/V *South Pacific*, October 28 to December 1, 1974, 8 p.

_____, J. M. Coe, and F. M. Ralston. 1975. Cruise report: M/V *Bold Contender*, September 22 to December 4, 1975, 13 p.

Norris, K. S., and T. P. Dohl. 1974. Subject: Final report. Behavioral studies of tuna-porpoise interaction. National Oceanic and Atmospheric Administration Contribution 03-4-208-54. Submitted by University of California, Santa Cruz. National Marine Fisheries Service, 102 p.

Perrin, W. F. 1970. Cruise report: M/V *Conquest*, December 21-22, 1970, 7 p.

_____. 1970. Cruise report: R/V *Cromwell*, September 3-4, 1970.

_____. 1970. Cruise report: ARV *Miss Behavior*, June 15-20, 1970.

_____. 1971. Cruise report: M/V *Westport*, September 7-8, 1972, 6 p.

_____. 1971. Cruise report: M/V *San Juan*, May 14-15, 1971, 2 p.

_____, and J. R. Hunter. 1972. Escape behavior of the Hawaiian spinner porpoise (*Stenella* cf. *S. longirostris*). Fish. Bull., U.S. 70:49-60.

_____, R. L. McNeely, D. B. Holts, and J. M. Coe. 1972. Cruise report: M/V *Independence*, September 27 to October 29, 1972, 17 p.

Peters, C. B. 1978. Cruise Report: M/V *Marla Marie*, November 2 to December 25, 1977, 5 p.

Powers, J. E., R. W. Butler, J. G. Jennings, R. McLain, C. B. Peters, and J. DeBeer. 1979. Summary of research results from the fourth cruise of the dedicated vessel, September 12 to October 31, 1978. SWFC Admin. Rep. LJ-79-14, 42 p.

Stephens, T. C., and T. N. Delmer. 1981. Extension of the numerical simulation of the purse seine fishing process, final report. Beers Associates, Inc. Contract 80-ABC-00182. *In* SWFC Admin. Rep. LJ-81-13C, 122 p.

_____, _____, and J. M. Coe. 1982. Simulation of changing and breaking cable and net structures, p. 773. *In* Proc. Oceans 82 Conf. Mar. Technol. Soc., Wash., D.C.

Twohig, D. J. 1975. Cruise report: M/V *J. M. Martinac*, October 30 to December 21, 1974, 6 p.

Wathne, F. 1973. Cruise report: M/V *Independence*, January 1 to February 13, 1973, 3 p.

[15]The cruise reports in this bibliography are available through the Chief, Oceanic Fisheries Resources Division, Southwest Fisheries Center, P.O. Box 271, La Jolla, CA 92038. Contract reports, SWFC Administrative Reports, and NMFS Technical Memoranda are available through the Director of the Southwest Fisheries Center or directly from the individual authors. Articles published in independent journals are available from the authors.

History of Artificial Propagation of Coho Salmon, *Oncorhynchus kisutch*, in the Mid-Columbia River System

ROY J. WAHLE and ROGER E. PEARSON

Introduction

Since the beginning of the 20th century, fish managers in the mid- and upper Columbia River have turned to hatcheries for a supply of anadromous fish. Prior to its settlement, the area was noted for its natural Pacific salmon *Oncorhynchus* spp., resources; but, as these resources began to decline, artificial propagation was attempted.

The first hatcheries in the mid-Columbia section (Fig. 1) of the river—the area formed by the tributaries and main stem of the Columbia above the mouth of the Snake River, at river mile 325, to Chief Joseph Dam at river mile 545—were constructed on the Wenatchee and Methow Rivers in 1899. By 1914 both had ceased operation. A new hatchery was constructed on the Wenatchee River in 1913 and one on the Methow River in 1915, both downstream from

Roy J. Wahle, now retired, was with the Northwest Regional Office, National Marine Fisheries Service, NOAA, 847 N.E. 19th Avenue, Suite #350, Portland, OR 97232. Current address: Rt. 2, P.O. Box 21, Yamhill, OR 97148. Roger E. Pearson is with the NMFS Northwest and Alaska Fisheries Center, 2725 Montlake Boulevard East, Seattle, WA 98112.

ABSTRACT—The history of artificial propagation of coho salmon, Oncorhynchus kisutch, *in the mid-Columbia River region began in 1899 with the construction of salmon hatcheries on the Wenatchee and Methow Rivers by the Washington Department of Fish and Game. These early attempts at artificial propagation ended in 1931. In the early 1940's, the Federal Government, in a program to resume propagation activities in the region, built hatcheries on the Wenatchee, Entiat, and Methow Rivers. These hatcheries reared several species of salmon, but ceased work on coho salmon after 30-35 years and concentrated on other species. Meanwhile, in the early 1960's, the Washington Department of Fisheries began to rear coho salmon at new facilities along the mid-Columbia River. Coho salmon were first reared at Ringold Salmon Pond near Pasco, and they were later reared at two additional facilities; one located at Wells Dam and the other upstream of Rocky Reach Dam at Turtle Rock. Since 1899, a total of over 65 million juvenile coho salmon have been artificially propagated in the mid-Columbia region and released into the Columbia River system.*

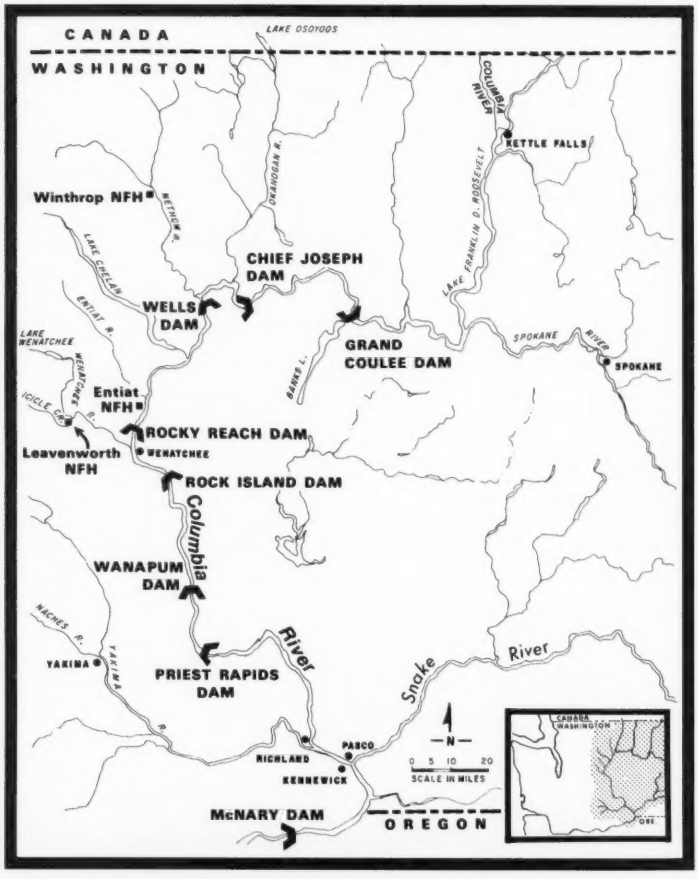


Figure 1.—Middle and upper portion of the Columbia River Basin.

Wenatchee Hatchery (left) near the Old Chiwaukum railroad station in about 1901. At right are the hatchery's fish racks which spanned the river and were erected each year following the spring-summer freshets.

the earlier locations. These early attempts at artificial propagation ceased in 1931.

Grand Coulee Dam on the upper Columbia River was built in the late 1930's, and the construction of this dam, which did not have a fishway to pass the anadromous stocks of the upper Columbia, gave rise to a major artificial propagation program (Neuberger, 1941). Large Federal hatcheries were constructed near Leavenworth, Entiat, and Winthrop, Wash., to provide runs of anadromous fish in the Columbia River Basin between Grand Coulee and Rock Island Dams (Fig. 1). Only limited success was achieved in the propagation efforts at the hatcheries. Part of the problem was that the knowledge and technology of rearing Pacific salmon and steelhead, *Salmo gairdneri*, was at an early stage of development; other handicaps centered on hatchery facilities and water supplies. In addition, the mix of species reared has varied considerably over the past 40 years, depending mainly on trends in management and advances in fish culture (Mullan[1]).

Following the construction of the Federal hatcheries, other artificial propagation facilities were built. All are operated by the State of Washington and most are funded by the Public Utility District (PUD) of the local area.

This article presents a brief history of the production of coho salmon, *Oncorhynchus kisutch* (also called silver or silverside), at mid-Columbia hatcheries. This article does not cover ecological information that can be used to elucidate reasons for the success or failure of hatchery operations. Instead, the article concentrates on dates of hatchery operation and numbers of fish released. Much of this information is only available in reports that have had limited distribution, and some information has never been published. This is rather surprising because at one time the hatchery operation on the mid-Columbia was North America's largest program of artificial fish propagation (Neuberger, 1941).

Of the five major river systems on the mid-Columbia (the Entiat, Methow, Okanogan, Wenatchee, and Yakima), all except the Okanogan at one time held native populations of coho salmon (Craig and Suomela[2], Davidson[3]). Considering the location of the spawning grounds utilized by this species in the regions adjacent to the northern North Pacific Ocean, the aforementioned rivers are moderately distant from the ocean. McPhail and Lindsey (1970), on one hand, describe coho salmon spawning in the Yukon River 1,152 miles from the ocean, and Gribanov (1948) reports that on the Kamchatka Peninsula, U.S.S.R., their spawning grounds frequently extend beyond the upstream limits of sockeye, *O. nerka;* pink, *O. gorbuscha;* and chum, *O. keta,* salmon. Yet Godfrey (1965) finds it more common, at least in North America, for coho salmon to spawn within 150 miles of the ocean.

Anadromous fish runs in the mid-Columbia were influenced by agricultural practices and exploitation of resources, such as mining of metals, as early as the last half of the 19th century—as demonstrated by the need for the hatcheries constructed in 1899 on the Methow and Wenatchee

[1]Mullan, J. W. 1980. Ecological overview, coho salmon (*Oncorhynchus kisutch*) propagation, Mid-Columbia River. Admin. Rep. 1, 51 p. Fisheries Assistance Office, U. S. Fish and Wildlife Service, Route 1, P.O. Box 123-A, Leavenworth, WA 98826.

[2]Craig, J. A., and A. J. Suomela. 1941. Appearance of the runs of salmon and steelhead trout native to the Wenatchee, Entiat, Methow, and Okanogan Rivers. Unpubl. rep., 35 p. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Seattle, Washington. (Available from Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.)

[3]Davidson, F. A. 1965. The development of irrigation in the Yakima River basin and its effect on the migratory fish populations in the river. Unpubl. rep., 14 p. Grant County Public Utility District, P.O. Box 878, Ephrata, WA 98823.

Rivers. Furthermore, the runs had been destroyed or almost destroyed by the construction of impassable dams, unscreened irrigation diversions, and overharvest prior to completion of Grand Coulee Dam in 1941 (Bryant and Parkhurst, 1950; Craig and Suomela, footnote 2; Davidson, footnote 3).

Abundance and Life History of Columbia River Coho Salmon

Coho salmon are second to chinook salmon, *O. tshawytscha,* as the most numerous salmon species in the Columbia River Basin. Columbia River coho salmon support extensive commercial and sport fisheries off the Pacific Coast from northern California to southern British Columbia as well as a major river fishery (Lander and Henry, 1973; Wahle et al., 1974).

Over the years, the catch of coho salmon in the Columbia River has varied extensively (Craig and Hacker, 1940; Fulton, 1970). It is evident, however, that coho salmon were most abundant in the early years of the fishery when annual catches reached 700,000-900,000 fish, and that they declined rapidly in the late 1930's (Fig. 2). Catches remained low until the mid-1960's when hatchery production increased sharply.

Data do not exist on the early abundance of mid-Columbia coho salmon. The records of early settlers, however, indicate that virtually all of the streams in this area supported relatively large runs of coho salmon (Bryant and Parkhurst, 1950; Craig and Suomela, footnote 2; Davidson, footnote 3).

At one time, the Columbia River was the greatest salmon and steelhead river in the world. The fish originated in the thousands of miles of streams, migrated to the ocean, grew to adulthood, and migrated back to their natal streams to spawn and die, completing the life cycle. The population did not consist of one large mass of fish that randomly distributed itself throughout the system, with free interbreeding occurring between all fish. Instead, a complex of subpopulations evolved with segregated spawning units (Mullan, footnote 1).

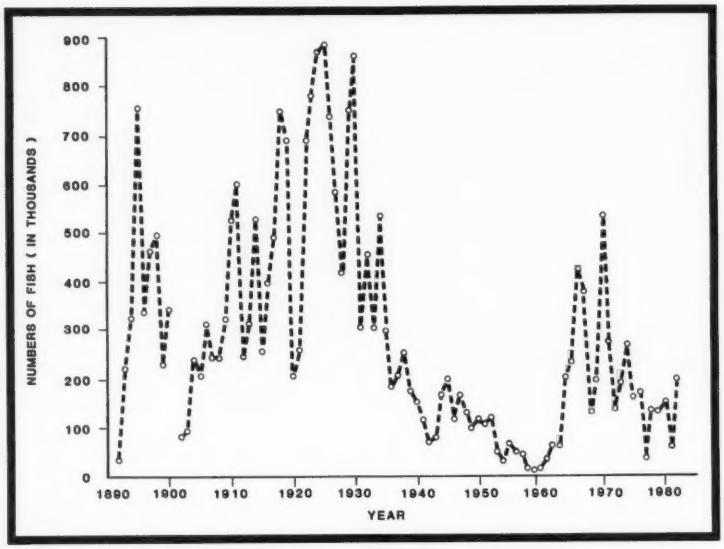


Figure 2.—Commercial catch of coho salmon (by net) in the Columbia River, 1891-1982.

Table 1.—Available information on spawning of coho salmon at Leavenworth and Winthrop National Fish Hatcheries (from Mullan, text footnote 1).

Hatchery and year	Arrival dates	Spawning dates	No. fish spawned		Average no. of eggs/female
			Males	Females	
Leavenworth					
1940			4	2	3,700
1941		10/24-11/7	4	6	2,600
1944	9/30-11/7	10/10-11/8	57	66	3,077
1945			3	1	2,947
1947		10/28-11/28	72	80	2,635
1950		12/7			2,421
1966			49	51	3,078
1967			7	11	2,727
1968	9/13	10/2	375	689	3,027
1970	10/20	11/18	236	204	3,317
1971				408	3,126
1972				7	3,143
1973	8/30-10/29	10/29[1]	28	39	3,017
Winthrop					
1947[2]		11/13-12/3			2,092
1950		10/25-12/10	9	7	3,806
1953			3	3	2,824
1954			2	1	2,954
1962[3]	10/9	10/10	64	119	2,926

[1]Peak of spawning.
[2]Fish reported in poor condition; some were spawned out.
[3]Fish reported in excellent condition.

Mullan (footnote 1) has reported that records of arrival and spawning dates for coho salmon returning to the Leavenworth and Winthrop National Fish Hatcheries (NFH) of the mid-Columbia are incomplete and inconsistent (Table 1); and there are no records of adults returning to Entiat NFH. Indigenous (i.e., mid- and upper Columbia River) coho salmon held at Leavenworth NFH on the Wenatchee River were known to have spawned in late October-early November in 1941 and 1944. Nonindigenous stock returning to Winthrop

NFH on the Methow River were spawned into December in some years; the fish were reported to be in poor condition and partially spawned out. Likewise, fish counting in the 1970's was extended into late November or mid-December at Rock Island and Rocky Reach Dams to count large numbers of coho salmon passing during this period.

Adult coho salmon enter their streams of origin between July and February and spawn from September through March. The species is categorized into seasonal runs depending on the time of year that adult fish arrive in the river to spawn. Late summer and fall runs are the stocks that are usually used in hatcheries.

Coho salmon spawn in the fall or winter, and the resultant fry emerge from the gravel in early spring. Nearly all Columbia River fry remain in fresh water for 1 year prior to migration to the ocean in the spring of their second year of life. Some male coho salmon spend only about 6 months in the ocean before returning to their natal stream to spawn. These fish, said to be 2 years old, are called jacks. Most Columbia River fish, however, spend about 18 months in the ocean and return to spawn as 3-year-olds (Marr, 1943).

Egg number varies with body size, geographical area, and year. In Washington, this number ranges from 1,440 to 5,700 for females 17.3-28.3 inches in length. The numbers range from 2,100 to 2,789 in British Columbia where the usual weight of commercially caught fish is 8 pounds, with most ranging from 5 to 12 pounds and with 20-pound fish not uncommon (Scott and Crossman, 1973).

Mullan (footnote 1) reported that the data on average number of eggs per female spawned at Leavenworth and Winthrop NFH are relatively complete, but that data on size of fish spawned are almost totally lacking (Table 1). Fulton (1970) reported that coho salmon returning to Leavenworth NFH in 1968 weighed 12-15 pounds compared with an average weight of 9.9 pounds for Columbia River fish. Although none returned to Leavenworth NFH, progeny of Lewis River coho salmon that were reared at Leavenworth NFH and then recovered as adults during 1945 in the lower Columbia River commercial fisheries were smaller than the above; 89 females averaged 9.6 pounds and 27.0 inches, and 121 males averaged 9.3 pounds and 26.3 inches (Fulton and Pearson, 1981). The average number of eggs per female was about 3,000 at Leavenworth and Winthrop NFH (Table 1).

Artificial Propagation Before Construction of Grand Coulee Dam

Although there are five major river systems in the mid-Columbia, artificial propagation was only carried out in two, the Wenatchee and Methow, prior to construction of Grand Coulee Dam. Both rivers flow southeasterly from the Cascade Mountains and are primarily maintained by melting snow and glaciers. There is about a 50-inch difference in precipitation between the subalpine forests of the headwaters and the semiarid region at the confluences with the Columbia River in north-central Washington. These are gravelly rivers, with wide fluctuation in flow associated with the climatic and geological characteristics of the region (Mullan, footnote 1).

Wenatchee River

The first hatchery on the Wenatchee River was constructed in 1899 about 40 miles upstream from the Columbia River near the (then) Chiwaukum railroad station above Tumwater Canyon (WDFG, 1902). In 1904 the hatchery was closed. Reasons given for the closure were extreme cold weather, heavy snow, isolated location and consequent expense of operation, freshets, and that it was too far up the river to secure the best variety of fish which was spring chinook salmon. A quotation from the 14th and 15th annual reports of the State Fish Commissioners of Washington states: "If it [the hatchery] had been below the Tumwater Canyon, the early chinook could have been secured; as it is it takes only an inferior run of silversides" (WDFG, 1903-04).

The next hatchery on the river began to propagate fish in 1913. This state facility was constructed farther downstream, about 25 miles upstream from the Columbia at the town of Leavenworth. An important reason for selecting this location was the premise that large numbers of spring chinook salmon could be taken. However, few eggs of spring chinook salmon or any other species were obtained at this site, and the hatchery was abandoned in 1931. Data, which are probably incomplete, indicate that two lots of coho salmon eggs were collected, 30,000 and 38,500, and one lot of 3.8 million fry planted (1903) that were progeny of lower Columbia River stocks (Craig and Suomela, footnote 2).

Methow River

The first hatchery on the Methow River was built in 1899 at the mouth of the Twisp River. It produced mainly coho salmon. Almost 12 million coho salmon eggs were taken from 1904 to 1914 (Craig and Suomela, footnote 2).

In 1915, at Pateros near the mouth of the Methow River, the Washington Water Power Company constructed a dam which was not provided with fishways (Bryant and Parkhurst, 1950). Since the dam was impassable, the hatchery was moved downstream of the dam site. Coho salmon eggs continued to be taken—about 3.5 million from 1915 to 1920. The run declined following the move, and no eggs were taken after 1920, although the hatchery continued to operate until 1931 with eggs and fry of steelhead and chinook and chum salmon from other rivers.

Artificial Propagation After Construction of Grand Coulee Dam

Federal- and Washington-operated hatcheries other than the ones already described have also reared coho salmon on the mid-Columbia. These propagation activities are related to the development of hydroelectric power on the Columbia River and

started with the construction of Grand Coulee Dam. Rock Island, Bonneville, and Grand Coulee Dams began operation in 1933, 1938, and 1941, respectively, and were followed by additional dams (Fig. 1). All of these dams have had a detrimental and cumulative effect on runs of wild fish and returns from hatchery releases in the upper and mid-Columbia River.

Federal Hatcheries

Federal hatcheries were constructed near Leavenworth on Icicle Creek, a tributary of the Wenatchee River; near Entiat on the Entiat River; and near Winthrop on the Methow River. At the time the three hatcheries were designed, their projected total production was estimated at over 100 million salmon and steelhead juveniles. There were limiting deficiencies in the original plans, however, and production never reached this level (Fish and Hanavan, 1948). Leavenworth NFH was the center of the fish-culture operation. Following artificial spawning of the fish, eggs were incubated at Leavenworth NFH, and subsequently some of the eggs were shipped to Entiat NFH and Winthrop NFH for hatching, rearing, and release as fingerlings. Although there have been many changes over the years, Leavenworth NFH is still the largest, with a production capacity of about 2.5 million juveniles, followed by Winthrop NFH (1 million), and Entiat NFH (0.6 million). Currently, production at the hatcheries is almost exclusively devoted to spring chinook salmon in keeping with the goals of a comprehensive management plan for the mid-Columbia River (Mullan, footnote 1).

Leavenworth NFH is located about 500 miles from the ocean. Holding ponds for retaining adult fish prior to spawning were formed in a ¾-mile section of Icicle Creek bypassed by a diversion canal. Construction of four dams created three separate river-holding areas. Retrieval of fish was carried out by seining or various trapping schemes either in the holding areas or the tailrace of the bypass diversion canal dam.

Table 2.—Releases and returns of coho salmon reared at Leavenworth National Fish Hatchery (NFH).

Brood year	Egg source[1]	Releases				Returns	
		Area	Number	Date	Fish/lb.	Trapped	Obs./est.
1940	Rock Island[2]	Icicle Creek	5,470	1942	11.4		
1941	Rock Island[2]	Icicle Creek	11,050	1943	11.4	128	
1942	Lewis River	Icicle Creek	40,370	1943	91.0	4	
	Lewis River	Icicle Creek	69,627	1944	91.0		
1943	Lewis River	Icicle Creek	112,267	1944	91.0	1	
1944	Icicle Creek	Icicle Creek	133,703	1945	47.0	166	
	Lewis River	Icicle Creek	28,954	1945	24.8		
1945	Icicle Creek	Icicle Creek	1,896	1946	26.0		
1946			0			1	
1947	Icicle Creek	Icicle Creek	114,652	1948	60.2	22	
1948			0				
1949	Lewis River	Wenatchee River[3]	229,969	Oct. 1950	27.6		
1950	Lewis River	Icicle Creek	98,786	1952	16.6	4	
	Icicle Creek	Icicle Creek	16,850	1952	16.6		
1951	Lewis River	Icicle Creek	47,607	1953	23.2	3	
1952	Lewis River	Icicle Creek	93,909	1954	42.4		
1953	Icicle Creek	Icicle Creek	2,419	1954	142.3		
1954	Quilcene	Icicle Creek	11,750	1955	50.0		
	Icicle Creek	Icicle Creek	3,222	1956	25.4		
	Quilcene	Icicle Creek	12,499	1956	38.0		
1955			0				
1956			0				
1957	Icicle Creek	Icicle Creek	2,884	Mar. 1959	27.7		
1958			0				
1959			0				
1960			0				
1961			0			15	150
1962	Eagle Creek	Icicle Creek	455,713	Aug. 1963	118.0		
1963	Eagle Creek	Icicle Creek	871,000	Oct. 1964	62.0	1,025	—[4]
1964	Cascade	Icicle Creek	769,000	Sept. 1965	41.0	461	
	Cascade	Icicle Creek	656,000	March 1966	16.0		
1965[5]	Cascade	Wenatchee River	4,170,000	July-Sept. 1966	54.0	2,286	2,350
	Cascade	Icicle Creek	536,000	March 1967	19.2		
	Cascade	Snake River	708,000	April 1967	16.0		
1966	Little White Salmon	Icicle Creek	125,000	March 1968	23.0	12	
	Little White Salmon	Icicle Creek	550,000	March 1968	18.0		
	Little White Salmon	Snake River	700,000	April 1968	20.0		
	Little White Salmon	Wenatchee River	3,701,000	April 1967	150.0		
1967	Icicle Creek	Icicle Creek	26,000	April 1969	18.0	1,031	1,131[6]
	Little White Salmon	Wenatchee River	4,397,000	July 1968	412.0		
	Little White Salmon	Icicle Creek	727,000	April 1969	18.0		
	Little White Salmon	Snake Creek	102,000	May 1969	18.0		
1968	Icicle Creek	Icicle Creek	2,231,000	Sept. 1969	47.0	2,778	
	Little White Salmon	Icicle Creek	908,000	April 1970	16.0		
1969[7]	Willard & Icicle	Icicle Creek	1,457,000	March 1971	15.0	7	
1970	Unknown	Icicle Creek	1,102,000	March 1972	15.0	477	
1971	Icicle Creek	Icicle Creek	233,000	May 1972	313.0	67	
	Icicle Creek	Icicle Creek	341,000	May 1972	195.0		
	Icicle Creek	Icicle Creek	734,000	April 1973	18.0		
1972	Willard	Icicle Creek	156,000	April 1974	16.0		
	Eagle Creek	Snake River	645,000	April 1974	21.0		
1973	Eagle Creek	Icicle Creek	659,000	April 1975	5.0		
		Total	27,997,597				

[1]Refers to either river of origin or hatchery located on river of origin as listed in Wahle and Smith (1979).
[2]From brood stock intercepted at Rock Island Dam.
[3]Stocked in Wenatchee River below Dryden Dam.
[4]5,000 jacks estimated.
[5]About 1,734,000 fry, progeny of Little White Salmon NFH stock, were released in Icicle Creek in March 1966; little if any survival was expected.
[6]100 Additional jacks estimated.
[7]About 2 million fry, progeny of Little White Salmon NFH stock, were released in Icicle Creek in March 1969; little if any survival was expected.

Entiat NFH and Winthrop NFH are located about 490 and 570 miles from the ocean, respectively. No provisions for holding adult fish were in the original plans for either hatchery. To remedy this deficiency, holding ponds connected to the rivers by short fish ladders werre constructed during World War II. In subsequent years these facilities were upgraded on a year-by-year basis, including construction of weirs to divert runs into the holding ponds.

Propagation of coho salmon at the

Table 3.—Releases of coho salmon reared at Entiat National Fishery Hatchery.

Brood year	Egg source	Releases			
		Area	Number	Date	Fish/lb.
1943	Lewis River	Entiat River	28,954	1944	91.0
1944	Lewis River	Entiat River	99,485	Oct. 1945	30.0
1963	Lower Columbia[1]	Entiat River	106,425	March 1965	29.0
1964	Lower Columbia	Entiat River	367,457	Sept. 1965	31.0
1965	Lower Columbia	Entiat River	275,000	June 1966	250.0
	Lower Columbia	Entiat River	299,855	Sept. 1966	52.0
1966	Lower Columbia	Entiat River	703,146	Oct. 1967	22.0
1967[2]	Lower Columbia	Entiat River	430,564	April 1968	644.0
	Lower Columbia	Entiat River	452,929	Oct. 1968	32.0
1968	Little White Salmon	Entiat River	588,745	July 1969	167.0
		Total	3,352,560		

[1]Lower Columbia River hatcheries are given in the annual report as the source of eggs; the specific source, however, is probably the same as the sources given for the same brood year at Leavenworth NFH (Table 2).
[2]About 1,672,000 fry were released in the Entiat River during April 1969; little if any survival was expected.

Table 4.—Releases of coho salmon reared at Winthrop National Fishery Hatchery.

Brood year	Egg source[1]	Releases			
		Area	Number	Date	Fish/lb.
1944	Carson	Methow River	40,082	Nov. 1945	91.0
1947	Methow River	Methow River	6,203	1949	24.0
1950	Methow River	Methow River	21,255	1952	20.0
	Lewis River	Methow River	149,578	1952	20.0
1951	Lewis River	Methow River	90,000	1953	15.0
1952	Lewis River	Methow River	94,514	1954	20.0
1953	Methow River	Methow River	6,840	1954	91.0
1954	Methow River	Methow River	1,493	1956	20.0
1958	Quilcene	Methow River	183,691	1959	19.0
1959	Eagle Creek	Methow River	638,039	Sept. 1960	28.0
1961	Eagle Creek	Methow River	327,653	1962	37.0
1962	Eagle Creek	Methow River	1,448,447	1963	44.0
1963	Big Creek	Methow River	824,045	1964	30.0
1964	Eagle Creek	Methow River	1,306,901	1965	40.0
1965[2]	Little White Salmon	Methow River	1,623,178	1966	58.0
1966[3]	Little White Salmon	Methow River	600,284	1967	48.0
1967[4]	Little White Salmon	Methow River	400,844	1968	24.0
1968	Little White Salmon	Methow River	113,778	1969	30.0
		Total	7,876,825		

[1]Refers to either river of origin or hatchery located on river of origin as listed in Wahle and Smith (1979).
[2]About 450,000 fry were released in the Methow River during 1965; little if any survival was expected.
[3]About 382,000 fry were released in the Methow River during 1966; little if any survival was expected.
[4]About 419,000 fry were released in the Methow River during 1967; little if any survival was expected.

three Federal hatcheries developed in two phases (Mullan, footnote 1). The first phase began with the completion of the hatcheries in the early 1940's. These hatcheries were a major component of a program of natural and artificial propagation envisioned in the Grand Coulee Fish-Maintenance Project (Fish and Hanavan, 1948). During this period, hatchery operations centered around sockeye and chinook salmon, and relatively few coho salmon were produced. In spite of bottlenecks in the facilities and other unanticipated problems, large numbers of fish were reared and released (Fish and Hanavan, 1948); but, after a number of years it became apparent at all Columbia River Basin hatcheries that the survival of artificially propagated salmon and their contribution to the fisheries were not as large as had been expected.

The second phase of rearing coho salmon, which began in the early 1960's, was related to advances in fish culture, particularly in the areas of fish nutrition and feeding, and to a change in philosophy to raising fewer fish to a larger size (Wahle and Smith, 1979). During this period, the production of coho salmon greatly increased, and increases in the survival of hatchery fish and their contribution to the fisheries were evident (Cleaver, 1969; Wahle and Smith, 1979).

This second phase of rearing coho salmon lasted until 1969 at Winthrop NFH and Entiat NFH, and until 1975 at Leavenworth NFH, when these hatcheries concentrated on rearing spring chinook salmon (Smith and Wahle, 1981).

About 28 million juvenile coho salmon, representing 26 brood years, were released from Leavenworth NFH from 1942 to 1975, primarily into the Wenatchee River system (Table 2). Over 3 million juveniles, representing 8 brood years, were released from the Entiat NFH into the Entiat River from 1944 to 1969 (Table 3). Slightly less than 8 million juvenile coho salmon, representing 17 brood years, were released from the Winthrop NHF into the Methow River from 1945 to 1969 (Table 4).

The coho salmon eggs used at the hatcheries were obtained from adults from many different spawning areas (Tables 2-4). The majority of juveniles released were progeny of lower Columbia River stocks because the upper and mid-Columbia stocks were too depleted to supply the hatcheries. Estimates of the abundance of these upper and mid-Columbia stocks can be obtained from examination of the number of adults migrating past dams downstream from the hatcheries on the main stem Columbia. In years 1933-39, for example, from 10 to 183 adult coho salmon were recorded annually passing Rock Island Dam at river mile 453 (Fig. 3). In 1940, 1941, and 1942, when the hatcheries became operational, coho salmon trapped at Rock Island Dam were 12, 29, and 1, respectively. Two females were spawned from the 12 taken in 1940; yielding a release of 5,740 juveniles from Leavenworth NFH into Icicle Creek in spring 1942. Six females were spawned from the 29 fish intercepted at Rock Island Dam in 1941, and the resulting 11,050 juveniles were released into Icicle Creek during the spring of 1943. The run in 1942 consisted of one fish and, in 1943, the 22 fish collected all died; consequently no eggs were taken in either year.

The first adult coho salmon from these efforts returned to Icicle Creek and Leavenworth NFH in 1944—125 3-year-olds and 3 jacks out of the (then) record run of 186 passing Rock Island Dam (Fig. 3). Although the 125 3-year-olds were not marked (the 3 jacks were marked fish of Lewis River stock released earlier in 1944), these fish were intuitively the adult returns of the 11,050 juveniles released in spring 1943, which were in turn the progeny of the 6 females spawned in 1941. Sixty-six females were spawned in 1944 yielding 203,093 eggs and ultimately 133,703 fingerlings that were released into Icicle Creek in 1945.

Subsequent returns to Leavenworth hatchery of later generations of mid- and upper Columbia River stocks were masked by coincidental releases of progeny of lower Columbia River stocks. For example, 166 coho salmon returned to Leavenworth in 1947, again out of a (then) record count of 229 at Rock Island Dam. These returnees are essentially attributable to 1945 releases of progeny of Icicle Creek and Lewis River stocks. From this collection of mixed stock returnees in 1947, 80 females were spawned, ultimately resulting in a release of 114,652 fingerlings in 1948.

There are indications that during this period the value of using indigenous stocks for reestablishing the runs was slowly being recognized (Mullan, footnote 1). The authors of the Leavenworth NFH annual reports state that coho salmon runs occurred every third year and that attempts to establish runs in the off years were unsuccessful. The 22 adult coho salmon noted as passing Rock Island Dam in 1943, after the initial interception and relocation phase of the Grand Coulee Fish-Maintenance Project was completed, were trapped for spawning purposes but died prior to use. Early run coho salmon passing Bonneville Dam were collected and held at the old Carson NFH for spawning, but these, too, died. The Washington Department of Fisheries (WDF) Director's initial offer of Lewis River coho salmon as a substitute for indigenous stock was accepted with reluctance, Mullan (footnote 1) noted that in the 1942 annual report, District Supervisor Kemmerick, concerned about disease problems at the Leavenworth hatchery, wrote:

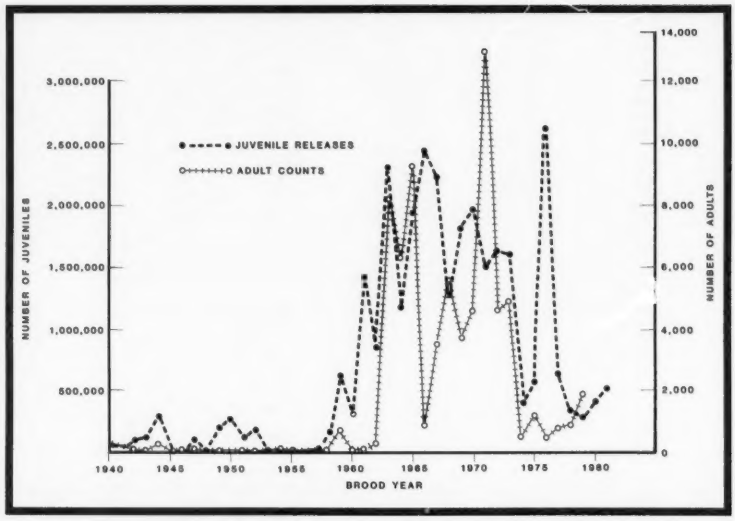


Figure 3.—Comparison of coho salmon adults counted at Rock Island Dam and juveniles released from mid-Columbia River hatcheries, brood years 1940-81.

"The small lot of silver salmon fingerlings produced from eggs of two females spawned in the fall of 1940 were liberated on April 28 and never became affected with any disease. Likewise, the silver salmon fingerlings produced from the small lot of eggs taken in the fall of 1941 have outgrown any other fish on hand and have never required a treatment of any kind."

The point to be emphasized here in relation to reestablishing the coho salmon runs by artificial propagation is the different rates of survival of indigenous and nonindigenous stocks, as documented by Ricker (1972). Coho salmon stocks, like most other anadromous salmonid stocks, have evolved over thousands of years to develop discrete populations, each with subtle life history differences, each homing to specific areas. The ever increasing use of eggs from nonindigenous stocks that were not adaptable to the mid-Columbia probably led to lower rates of survival than were needed to develop viable runs of coho salmon.

The return of 125 adults in 1944 from the 1941 brood year release (11,050 juveniles) of indigenous stock, discussed previously, was good (1.13 percent). However, the lack of return from the smaller plant (5,740 juveniles) of the 1940 brood year created a problem in the establishment of a viable run. Low returns became even more of a problem in later years with increased releases of nonindigenous stock. Nevertheless, a tenuous relation does exist between annual coho salmon counts at Rock Island Dam, which rose from less than a few hundred fish in the 1940's to the thousands beginning in the mid-1960's, and the second phase of more numerous hatchery releases of juveniles beginning in the early 1960's (Fig. 3).

The number of adult coho salmon returning to Icicle Creek and Leavenworth NFH is shown in Table 2. This production has been reconstructed by Mullan (footnote 1) as follows:

1966—1,025 adults trapped, with another 5,000 jacks estimated; 1967—a good run estimated but only 461 collected due to washout of the trap; 1968—2,286 trapped out of an estimated total run of 2,350 fish; 1969—run largely blocked because of construction at John Day Dam in the lower Columbia River; 1970—1,031 trapped with about 100 adults and 100 jacks estimated remaining in Icicle Creek; 1971—2,778 trapped; 1972—some fish observed but only a few entered the trap (this was attributed to higher-than-normal stream flow); 1973—large number observed spawning in Icicle Creek but only 477 collected; and 1974—observations of a good run but trapping abandoned with only 67 fish collected incidental to the recovery of chinook salmon spawners.

The survival of hatchery propagated fish from the time of their release to the time of their return varies between brood years. Some information on the subject is available for Columbia River coho salmon in Wahle et al. (1974). Here, juvenile coho salmon of the 1965-66 broods were marked at 20 hatcheries, and survival rates back to the hatcheries were 0.9 percent for the 1965 brood and 0.7 percent for the 1966 brood. The rates at Leavenworth NFH were lower than these averages. The return of fish to the mid-Columbia hatcheries, however, does not give the total picture of the success of their operation. For example, Fulton and Pearson (1981) reported good catches of marked coho salmon in the river fishery but no returns to Leavenworth NFH.

Entiat NFH released juvenile coho salmon in 1944-45 and 1965-69 (Table 3). There is no record of a return from these releases. The Entiat River, however, did not have a weir near the hatchery to trap and collect adult salmon during this period, and there is a possibility that adults did return to the river but migrated upstream past the hatchery.

Winthrop NFH released juvenile coho salmon in 1945, 1949, 1952-54, 1956, 1959-60, and 1962-69 (Table 4). The number of returning adults taken at the hatchery was by year: 1947, 41; 1950, 23; 1953, 6; 1954, 3; 1962, 250. The 250 adults taken in 1962 were a part of the record run at Rock Island Dam (Fig. 3); the 737 fish counted at the dam was the highest number of coho salmon observed in any previous year since the dam was completed in 1933. The years 1947, 1950, 1953, 1954, and 1962 were noteworthy at Winthrop NFH because a weir was used to trap and collect adult fish. There are no records of coho salmon being taken in other years, but weirs were not used in those years and there is a possibility that adults did return to the river but migrated past the hatchery.

State Hatcheries

The WDF, in cooperation with the U.S. National Marine Fisheries Service (NMFS), started to rear salmon in the early 1960's near Pasco at Ringold Salmon Pond. The facility is a rearing pond, and, during the years 1963-72 and 1977-78, juvenile coho salmon were obtained from hatcheries on tributaries of the lower Columbia River and reared for release into the river above McNary Dam (Table 5). In later years, the facility concentrated on other species.

Propagation of salmon on the main stem of the mid-Columbia River was begun by the WDF and the PUD's of Chelan and Douglas Counties in the late 1960's to early 1970's (Table 6). Facilities were constructed 1 mile upstream of Rocky Reach Dam at Turtle Rock, adjacent to Priest Rapids Dam, and adjacent to Wells Dam. The three facilities were designed as spawning channels rather than conventional hatcheries. Coho salmon were only reared at Turtle Rock and Wells Dam. Initially, eggs

Table 5.—Releases of coho salmon reared at Ringold Salmon Pond.

Brood year	Releases		
	Number	Date	Fish/lb.
1962	35,000	Sept. 1963	31
1963	86,000	Dec. 1964	49
1964	161,000	Oct. 1965	141
1965	128,000	Oct. 1966	124
1966	None		
1967	322,000	Jan. 1969	15
1968	221,000	Mar. 1970	17
1969	264,000	Jan. 1971	13
1970	132,000	Feb. 1972	20
1971	None		
1972	None		
1973	None		
1974	None		
1975	None		
1976	1,029,000[1]	Oct. 1977	31
1976	1,102,000	Mar. 1978	9
1977	None		
1978	None		
1979	None		
1980	None		
1981	None		
Total	3,480,000		

[1]Released into the upper Yakima River system.

Table 6.—Number of coho salmon counted at Rocky Reach and Wells Dams and number of juveniles released from Rocky Reach (Turtle Rock) and Wells rearing facilities 1970-1983.

Year	Dam counts		Brood year	Number	Fish/lb.	Facility
	Rocky Reach	Wells				
1970	207	54	1967	190,000	26	Wells
1971	0	154	1968	54,000	25	Rocky Reach
1972	3,312	584	1969	100,000	25	Rocky Reach
1973	745	322	1970	736,000	9	Rocky Reach
1974	10,788	110	1971[1]	393,000	13	Wells
			1971	388,000	15	Rocky Reach
1975	6,979	26	1972	276,000	15	Wells
			1972	572,000	14	Rocky Reach
1976	5,685	97	1973[2]	420,000	18	Wells
			1973	548,000	13	Rocky Reach
1977	927	70	1974	402,000	14	Rocky Reach
1978	1,438	73	1975	584,000	13	Rocky Reach
1979	244	63	1976	512,000	12	Rocky Reach
1980	713	77	1977	640,000	27	Rocky Reach
1981	522	19	1978	353,000	13	Rocky Reach
1982	882	337	1979	296,000	12	Rocky Reach
			1980	429,000	13	Rocky Reach
			1981	515,000	16	Rocky Reach
			Total	7,408,000		

[1]83,000 submigrants (104/lb.) released September 1972 into the Wenatchee River.
[2]504,000 submigrants (525/lb.) released July 1974 into Icicle Creek (Wenatchee River).

were hatched at Leavenworth NFH and transferred to the Wells Dam and Turtle Rock facilities for rearing, but in later years eggs or fry were obtained from hatcheries on the lower Columbia River. After some adjustments in rearing and release of relatively large juveniles, success was reflected in fish counts at dams, particularly the run of 10,788 tallied over Rocky Reach Dam in 1974 (Fig. 3).

Compared with the earlier Federal propagation activities using colder water, releases of large juveniles (Table 6) were made possible by the warmer Columbia River water at Wells Dam and Turtle Rock rearing facilities and may account for the subsequent higher number of adults at Rock Island Dam. Also, many of the small juveniles released from the Federal hatcheries were not regular production fish; they were reared from surplus eggs taken at lower Columbia River hatcheries and released at submigrant size. The release of large juveniles may also have influenced the age composition of returning adults. Although the age composition was never determined, PUD personnel observed that the runs were heavily weighted towards jacks, especially the large escapement of 10,788 passing Rocky Reach Dam in 1974 (Mullan, footnote 1).

Summary

There are five major river systems in the mid-Columbia region: The Entiat, Methow, Okanogan, Wenatchee, and Yakima. Prior to development of the region, all systems except the Okanogan River were known to have relatively large runs of coho salmon. These runs had probably been influenced by environmental abuses as early as the last half of the 19th century—as demonstrated in 1899 by the construction of salmon hatcheries to enhance the natural production of local stocks.

From 1899 to the time of the construction of the Grand Coulee Dam in 1941, the only hatcheries in the mid-Columbia were operated by the State of Washington and were on the Wenatchee and Methow Rivers. On the Wenatchee River, the first hatchery was constructed in 1899 upstream of Tumwater Canyon. This hatchery was closed in 1904 because of the lack of spring chinook salmon, which was considered the most valuable fish for propagation, and because of problems related to the harsh climate and isolated location of the facility. Reports indicate that some coho salmon were reared at the hatchery, but they do not give the extent of the production. The next, and last, hatchery on the Wenatchee during this period was built in the town of Leavenworth in 1913. This hatchery also had difficulty obtaining eggs of spring chinook salmon and was abandoned in 1931. Records, which are probably incomplete, show that 2 lots of coho salmon eggs were collected, 30,000 and 38,500, and 1 lot of 3.8 million fry was planted that was progeny of lower Columbia River stocks.

Logging dam at Leavenworth, Wash., in about 1908. Cail Fishway is on the right; this type of fishway was not always an efficient passageway for salmon.

The first hatchery on the Methow River was constructed in 1899 at the confluence of the Methow and Twisp Rivers, producing mainly coho salmon. Its records of production are also incomplete, but we do know that from 1904 to 1914 almost 12 million coho salmon eggs were taken. The hatchery operation was moved in 1915, at which time a dam that did not have a fishway was constructed at Pateros near the mouth of the Methow River. The location of this hatchery was downstream of the dam, and a total of 3.5 million coho salmon eggs were taken at the site from 1915 to 1920. The run of coho salmon declined, however, and no eggs were taken after 1920, although the hatchery continued to operate until 1931 with eggs and fry of other species.

In the 1930's the main stem of the Columbia began to be changed from a free flowing river to a chain of large reservoirs formed by hydroelectric dams. These dams and reservoirs had a detrimental effect on stocks of anadromous salmon and steelhead that had already been diminished through other environmental abuses and overfishing, and fish managers turned to artificial propagation to compensate for the loss of these valuable fish.

The next hatcheries were built by the Federal Government during the early 1940's after the construction of the Grand Coulee Dam which did not have a fishway. They were operated by the Interior Department's U.S. Fish and Wildlife Service, and were located near Leavenworth on Icicle Creek, a tributary of the Wenatchee River; near Entiat on the Entiat River; and near Winthrop on the Methow River. Leavenworth NFH was the largest facility, and from 1942 to 1975 it released, mainly into the Wenatchee River system, about 28.0 million juvenile coho salmon. A total of about 3.4 million juvenile coho

salmon were released from Entiat NFH into the Entiat River from 1944 to 1969, and about 7.9 million juveniles were released from Winthrop NFH into the Methow River from 1945 to 1969. Most of these fish were progeny of lower Columbia River stocks.

From the early 1940's to the early 1960's, the major emphasis at the Federal hatcheries was on rearing of sockeye and chinook salmon and not on coho salmon. In the early 1960's, however, the propagation of coho salmon greatly increased because of improvements in fish culture and the availability of large number of eggs from the lower Columbia region. Production of the species continued until 1969 at Winthrop NFH and Entiat NFH and until 1975 at Leavenworth NFH, at which times these hatcheries concentrated on the rearing of spring chinook salmon.

In the early 1960's, the State of Washington began to raise salmon and steelhead at a number of new facilities along the mid-Columbia River. The first facility to rear coho salmon was Ringold Salmon Pond near Pasco. Here, the WDF, in cooperation with the NMFS, released a total of about 3.5 million juvenile coho salmon into the river during the years 1963-72 and 1977-78. The stocks for the pond were obtained from hatcheries on tributaries of the lower Columbia.

In the late 1960's and early 1970's, the WDF, in cooperation with PUD's of Chelan and Douglas Counties, began to rear fish at three other facilities on the main stem of the mid-Columbia River. These facilities were designed as spawning channels rather than conventional hatcheries and were located at Turtle Rock, upstream of Rocky Reach Dam; at Priest Rapids Dam; and at Wells Dam. Coho salmon were only reared at Wells Dam and Turtle Rock facilities. A total of about 1.3 million juvenile coho salmon were released from the Wells Dam facility into the Columbia River from 1970 to 1976, and about 6.1 million that were reared at Turtle Rock were released from 1971 to 1983. Initially, eggs were hatched at Leavenworth NFH and then transferred to the facilities for rearing; but in later years, eggs and fry were obtained from hatcheries on the lower Columbia River.

In summary, fishery agencies have operated salmon hatcheries in the mid-Columbia region for nearly a century; and, although their emphasis has been on the rearing of chinook and sockeye salmon, the total release of coho salmon has been tremendous. From 1899 to 1983, for example, hatchery records, which are incomplete, show that about 65.6 million juvenile coho salmon were released into the Columbia. The success of this hatchery operation is difficult to evaluate accurately. There is no doubt, however, that over the years many hundreds of thousands and perhaps millions of the adult coho salmon taken by fishermen off the Washington and Oregon coasts and in the Columbia River originated in the mid-Columbia hatcheries.

Acknowledgment

We would like to thank James W. Mullan, U.S. Fish and Wildlife Service, Leavenworth, Wash., for his role in the preparation of this article. Mullan's research on the salmon stocks of the mid-Columbia provided us with the impetus to complete this study, and his report, "Ecological overview, coho salmon (*Oncorhynchus kisutch*) propagation, Mid-Columbia River" (footnote 1), provided much of the data and served as the necessary precursor for our subsequent paper. Any inaccuracy in the compilation of hatchery data or in the interpretation of historical events is solely the responsibility of the authors.

Literature Cited

Bryant, F. G., and Z. E. Parkhurst, 1950. Survey of the Columbia River and its tributaries—Part 4. U.S. Dep. Inter., Fish Wildl. Serv., Spec. Sci. Rep. Fish. 37, 108 p.

Cleaver, F. 1969. Recent advances in artificial culture of salmon and steelhead trout of the Columbia River. U.S. Dep. Inter., Fish Wildl. Serv., Fish. Leafl. 623, 5 p.

Craig, J. A., and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bull. U.S. Bur. Fish. 49:133-216.

Fish, F. F., and M. G. Hanavan. 1948. A report upon the Grand Coulee fish-maintenance project 1939-1947. U.S. Dep. Inter., Fish Wildl. Serv., Spec. Sci. Rep. Fish 55, 63 p.

Fulton, L. A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River basin—past and present. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Spec. Sci. Rep. Fish. 618, 37 p.

_____, and R. E. Pearson. 1981. Transplantation and homing experiments on salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, in the Columbia River System: Fish of the 1939-44 broods. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Tech. Memo. NMFS F/NWC12, 97 p.

Godfrey, H. 1965. Coho salmon in offshore waters. *In* Salmon of the north Pacific Ocean; part 9, coho, chinook, and masu salmon in offshore waters, p. 1-39. Int. North Pac. Fish. Comm., Bull. 16.

Gribanov, V. 1948. Kizhuch (*Oncorhynchus kisutch* Walb.) biologicheskii ocherk (The coho salmon (*Oncorhynchus kisutch* Walbaum)—a biological sketch). Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 28:43-101. In Russian. (Transl., 1962, by Fish. Res. Board Can., Transl. Ser. 370, 83 p.)

Lander, R. H., and K. A. Henry. 1973. Survival, maturity, abundance, and marine distribution of 1965-66 brood coho salmon, *Oncorhynchus kisutch*, from Columbia River hatcheries. Fish. Bull. 71:679-695.

Marr, J. C. 1943. Age, length, and weight studies of three species of Columbia River salmon (*Oncorhynchus keta, O. gorbuscha,* and *O. kisutch*). Stanford Ichthyol. Bull. 2:157-197.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Board Can. 173, 381 p.

Neuberger, R. L. 1941. The great salmon mystery. Saturday Evening Post 214(11):20-21, 39, 41-42, 44.

Ricker, W. E. 1972. Heredity and environmental factors affecting certain salmonid populations. *In* R. C. Simon and P. A. Larkin (editors), The stock concept in Pacific salmon, p. 19-160. H. R. MacMillan Lectures in Fisheries, Univ. B.C., Vancouver.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184, 966 p.

Smith, R. Z., and R. J. Wahle. 1981. Releases of anadromous salmon and trout from U.S. and Canadian Pacific coast rearing facilities, 1960-1976. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Tech. Memo. NMFS F/NWC-6, 411 p.

Wahle, R. J., and R. Z. Smith. 1979. A historical and descriptive account of Pacific coast anadromous salmonid rearing facilities and a summary of their releases by region, 1960-76, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Spec. Sci. Rep. Fish. 736, 40 p.

_____, R. R. Vreeland, and R. H. Lander. 1974. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific salmon fisheries. Fish. Bull. 72:139-169.

WDFG. 1902. Thirteenth Annual Report of the State Fish Commissioner. Wash. Dep. Fish. Game, 93 p.

_____. 1903-04. Fourteenth and fifteenth Annual Report of the State Fish Commissioner. Wash. Dep. Fish. Game, 98 p.

Norwegian Salmon and Trout Farming

ROBERT J. FORD

Introduction

The development of Norway's Atlantic salmon, *Salmo salar,* and rainbow trout, *S. gairdneri*, farming in coastal waters is, in the opinion of many observers, the most significant event in the history of European aquaculture. Norwegian production of farmed salmon and trout has increased dramatically during the past decade, from only 500 metric tons (t) in 1971 to an estimated 15,500 t in 1983, and production is expected to double by 1990. Norway's production of farmed salmon and trout, the vast majority of which is exported, is in the forefront of fish farming developments in Europe and has been that aquaculture industry's most striking commercial success.

Farms and Methods

The success of saltwater aquaculture has attracted many former Norwegian fishermen, disillusioned with declining fishery catches, to apply for licenses to start a salmon or trout farm. It is estimated that between 20 and 30 percent of the license holders are former fishermen. Many of these potential salmon or trout farmers inhabit the isolated communities along the fjords and islands of the western coast of Norway (Fig. 1). The Norwegian Government encourages fish farming in the sparsely populated coastal regions for both strategic and social reasons. Government officials regard salmon fishing as one of the most lucrative commercial activities available to residents of many isolated coastal communities.

Modern fish culture methods have enabled aquaculturists to start with relatively small investments and gradually expand their operations. The Norwegian Government assists small operators by guaranteeing loans through the Regional Development Fund and the Agricultural Development Fund. The Government, however, has restricted salmon farming investments by large companies, and has also imposed a size restriction on salmon farms to limit the industry primarily to small, owner-operated farms. In 1973, a law limiting the size of salmon farms to a floating net cage capacity of 8,000 m^3 was enacted[1]. Farms having over 8,000 m^3 of cage capacity, but approved before 1973, were exempted from this law.

Norwegian statistics show that 286 marine fish farms[2] were operating during 1982. Although the Norwegian Government had in effect suspended the issuing of new licenses in 1977, it granted 100 new licenses in October 1983 for farms with a maximum net cage capacity of 5,000 m^3. Farms which had been operating continuously for at least 3 years before October 1983, are allowed to apply for permission to increase their cage capacity from 5,000 to 8,000 m^3 to improve their profitability.

Although most Norwegian fish farms are relatively small, a few large ones were in operation before the 1973 law restricted net cage capacities. The largest Norwegian fish farm, operated near Bergen by the Mowi Company[3], produces over 500 t of cultured salmon per year. The Mowi company was founded in 1969 and its shares are partly held by the state-owned Norwegian electric power company, Norsk Hydro[4]. Mowi has developed techniques for raising Atlantic salmon smolts and transferring them to saltwater cages in the fjords where they are protected and fed until reaching marketable size in 3-4 years. Mowi exported its first cultured salmon in 1971 and by the mid-1970's had expanded its production to the point where it could guarantee regular supplies to its major customers.

Production

Two species of fish are extensively cultured in Norway: Atlantic salmon and rainbow trout. In recent years, the Atlantic salmon has come to dominate the industry.

Atlantic Salmon

Norwegian culturing of the Atlantic

Robert J. Ford is Foreign Affairs Specialist, Western Europe, with the Branch of Foreign Fisheries Analysis (F/M321), National Marine Fisheries Service, NOAA, Washington, DC 20235.

[1]It is estimated that a farm with a capacity of 8,000 m^3 produces about 60 t of salmon annually (Edwards, 1978).

[2]Of this total, 215 farms raised Atlantic salmon and 189 raised rainbow trout. There were 118 farms which raised both salmon and trout.

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[4]Norsk Hydro's British subsidiary, Norsk Hydro U.K. Ltd., has purchased the U.K. fish-farming firm Golden Sea Produce, Ltd., and its subsidiary Scottish Sea Farms, Ltd.

Table 1.—Norway's farmed Atlantic salmon and rainbow trout production, 1971–86.[1]

Year	Production (t) Atlantic salmon	Rainbow trout	Total
1971	98	433	531
1972	146	778	924
1973	171	1,001	1,172
1974	601	1,726	2,327
1975	862	1,655	2,517
1976	1,431	2,045	3,476
1977	2,137	1,795	3,932
1978	3,540	2,105	5,645
1979	4,389	2,988	7,377
1980	4,312	3,668	7,980
1981	8,907	4,485	13,392
1982	10,266	4,690	14,956
1983[2]	17,500	3,000	20,500
1984[2]	24,500	3,750	28,250
1985[2]	35,000	4,500	39,500
1986[2]	47,500	4,500	52,000

[1]Sources: FAO Fisheries Statistics Unit, Department of Fisheries (1971–80 data). Royal Norwegian Embassy in Washington (1980–86 data).
[2]Norwegian Fisheries Ministry projections.

Figure 1.—The coast of Norway.

salmon began around 1970 and increased rapidly, from only about 100 t in 1971 to an estimated 17,500 t in 1983 (Table 1). At first, Norwegian salmon farmers had difficulties marketing their product. It was more expensive to farm salmon than to catch it in the wild, and many customers believed that cultured salmon was of inferior quality. Consumers, however, have found over the years that the quality of cultured salmon is the same, or better, than that of wild salmon. The controlled conditions under which salmon can be cultured and harvested enable fishermen to produce a high quality, uniform product. The average weight of farmed salmon is 4 kg, whereas the weight of wild salmon fluctuates from 1 to 9 kg. The high quality, uniform size and weight, and year-round availability of cultured salmon accounts for much of its marketing appeal.

The Atlantic salmon is the most important species cultured in Norway; its 1982 harvest represented about 70 percent of the total Norwegian farmed fish production. Salmon farming has proven to be a very profitable industry and most research currently being done on fish farming in Norway involves salmon. This effort has made Norway by far the world's leading producer of farmed Atlantic salmon with its 1981 harvest accounting for nearly 90 percent of the world total (Table 2). Furthermore, Norwegian officials expect that their

farmed Atlantic salmon production could reach nearly 50,000 t by 1986.

Rainbow trout

The production of rainbow trout, *Salmo gairdneri,* is not expected to increase significantly because its export possibilities are poor. Less than half of the trout harvested is exported, and the home market is limited because rainbow trout is not indigenous to Norwegian waters and is not well known to Norwegian consumers (Edwards, 1978). Also, broodstock for their rainbow trout must be taken from captive stocks because the species does not spawn naturally in Norway (Edwards, 1978).

Although production of rainbow trout increased from 400 t in 1971 to 4,700 t in 1982, its annual harvest is expected to stabilize at around 5,000 t. Trout farming, however, is still important because new fish farmers generally begin culturing trout, which are easier to rear than Atlantic salmon, before turning to the more profitable salmon culture.

Trade Associations

Norwegian aquaculturists have three organizations. The largest is the Norwegian Fish Farmers Association (NFFA) which was organized in 1970 and represents 70 percent of Norway's fish farmers. It lobbies the Norwegian Government and also deals with domestic and foreign buyers. NFFA represents almost all of the large producers. NFFA has its own magazine, the *National Fish Farmer,* which provides the largest information on fish-farming techniques and on new markets.

The Norwegian Trout Organization (NTO) was established in 1965. Representing over 50 percent of the rainbow trout farmers, the NTO buys trout from the smaller farms and sells it to processors, thereby giving the smaller producers a greater leverage in deciding market prices. The NTO also provides financial assistance to its members when necessary.

The Norwegian Meat Marketing Board (NMMB) became involved in salmon marketing in 1974. As a result of the expanding salmon farming industry, the NMMB began providing loans and marketing services. Most of the salmon farmers dealing with the NMMB are small producers.

Exports

Farmed Atlantic salmon has become an important Norwegian fishery export. In 1982, Norway exported 9,400 t of cultured salmon, or over 90 percent of its total farmed salmon production (Tables 1, 3). France was the main market, buying 2,700 t, or 30 percent of Norway's exported salmon that year. The Federal Republic of Germany (FRG) and Denmark also bought large quantities of the Norwegian salmon. Exports to the United States were 762 t in 1982, or about 8 percent of Norway's total salmon exports.

Exports of Norwegian farmed trout in 1982 amounted to 2,200 t, around 45 percent of the total trout production that year. Sweden, which imported 580 t of trout, was the largest single market. Other major markets were France, FRG, and Denmark (Table 3).

The success of Norwegian Atlantic salmon exports is due to several factors. The salmon is of very high quality and is mostly shipped fresh by the Scandinavian Airlines System. Because the fish are farmed and not caught in the wild, fresh shipments can be guaranteed at any time of the year, and are especially valued at those times when the catch of wild salmon is down. The high quality and year-round availability of Norway's farmed salmon makes it particularly valuable to such specialized customers as restaurants, hotels, gourmet stores, etc.

Impact on the United States

U.S. salmon fishermen are concerned about the impact which developments in Norway will have on their industry. The rapidly expanding production of Norwegian farmed salmon, the vast majority of which is exported, will mean increased competition for U.S. fishermen in both domestic and foreign markets. The excellent quality, freshness, and year-round availability of the Norwegian farmed salmon makes it a highly-valued commodity among demanding consumers.

Norwegian companies have targeted the United States as a primary market for their farmed salmon. Although the United States is a major salmon producing country, Norwegian export companies believe that they can successfully market substantially increased amounts of fresh Atlantic salmon in the United States[5]. In 1982, according to

Table 2.—World production of farmed salmon and trout, 1981.

Country	Production (t) Rainbow trout	Atlantic salmon
Denmark	19,000	
Finland	7,000	
France	21,000	
Germany (FRG)	12,000	
Italy	21,000	
Japan	20,000	
Norway	4,000	8,900
Sweden	2,000	
United Kingdom	5,200	1,000
United States	20,000	
Total	131,200	9,900

Source: Cedrins (1983).

Table 3.—Norwegian exports of farmed Atlantic salmon and rainbow trout, 1982.

Country	Exports (t) Salmon	Trout	Total
France	2,710	260	2,970
Germany (FRG)	1,850	350	2,200
Denmark	1,240	280	1,520
Sweden	590	580	1,170
United Kingdom	930	110	1,040
United States	762	243	1,005
Switzerland	350	140	490
Belgium	370	90	460
Spain	270	40	310
Finland	140	40	180
Netherlands	120	60	180
Japan	40		40
Other	40	5	45
Total	9,412	2,198	11,610

Source: Fisheries Attache, Royal Norwegian Embassy, Washington, D.C., pers. commun., 1984.

[5]The Norwegian salmon is generally shipped in Styrofoam containers, each fish individually wrapped in cellophane, by SAS to Kennedy Airport in New York.

Norwegian statistics, U.S. firms bought 760 t of farmed salmon from Norway, compared with only about 21 t purchased in 1981. These exports accelerated rapidly in 1983 and totalled 2,300 t valued at $16.8 million. Norwegian officials believe that the United States eventually will replace France (which imported 2,700 t of Norwegian farmed salmon in 1982) as Norway's major market for this commodity.

Norwegian salmon exporters also have well-established markets in Western Europe and are expanding their sales in other parts of the world. France, FRG, and Denmark each bought over 1,000 t of Norwegian salmon in 1982, and seven other European countries purchased significant quantities (Table 3). The Norwegians have also decided to try to increase exports to the Far East (despite the fact that Japan bought only 40 t of the farmed salmon in 1982) because of their success in shipping fresh salmon to the United States. The SAS airline is interested in planning marketing campaigns to establish new markets for fresh salmon shipments.

Although the United States exports much more salmon than Norway (about 135,000 t of Pacific salmon *Oncorhynchus* spp., in 1982 compared with about 9,000 t of Atlantic salmon for Norway; U.S. commercial fishermen catch almost no Atlantic salmon) and supplies most of the salmon for the domestic U.S. market, it faces strong competition from the Norwegians for "top-of-the-line" salmon. Since the U.S.-produced Pacific salmon is caught in the summer, it is available fresh for only a limited time, and most U.S. salmon is produced in frozen or canned form. The Norwegian product, on the other hand, can be shipped fresh year-round and is exported to the United States and other countries mainly in the winter and spring. The Norwegian product, furthermore, is the Atlantic salmon which many consumers value more highly than the Pacific salmon. Thus, Norway is able to compete effectively with the U.S. for "top-of-the-line" salmon. The export potential of Norway's Atlantic salmon is evidenced by the fact that it has even been sold in Seattle, Wash., one of the centers of the U.S. Pacific salmon industry.

Future of Norwegian Aquaculture

Prospects for farmed fish production in Norway are very good, and industry expansion, primarily salmon production, is expected to continue. The Norwegian Ministry of Fisheries, which is investing large amounts of time and money into the research and development of farmed fish in Norway, is very optimistic. The Ministry is, however, concerned that too rapid an expansion of salmon farms could lead to a decline in prices obtained by salmon aquaculturists.

As a result, the Ministry is attempting to encourage fish farmers to also begin working with other equally cost-beneficial species (i.e., cod). The decline of the once flourishing Norwegian cod fishery in recent years has led many scientists to experiment with cod farming. Early results of these experiments have been good, and Ministry officials hope that a lucrative farmed cod industry can one day help supplement dwindling natural resources.

Literature Cited

Cedrins, R. 1983. Aquaculture in Scandinavia. *In* Proceeding of the International Seafood Trade Conference, p. 191-206. Alaska Sea Grant Rep. 83-2.

Edwards, D. J. 1978. Salmon and trout farming in Norway. Fish. News Books, Ltd., Farnham, Surrey, Engl., 195 p.

Using Charterboat Catch Records for Fisheries Management

HAROLD A. BRUSHER, MARK L. WILLIAMS,
LEE TRENT, and BARBARA J. PALKO

ABSTRACT—A pilot survey to study the feasibility of using catch records from charterboats for obtaining daily catch and effort data was initiated on 28 March 1982. Nine charterboat captains produced records for 39,410 marine fishes caught in 4,392.0 trolling hours and in 919.5 hours using other fishing techniques. Captains were contracted to supply daily records of fishing zones, fishing method, and all species in their respective catches. Response rate (i.e., weekly submission of logs) was 90.4 percent for all boat fishing weeks between 28 March and 31 December 1982. The potential use of this type of recreational data is discussed.

Introduction

The Magnuson Fishery Conservation and Management Act of 1976 (Public Law 94-265) established a mandate and mechanism for managing commercial and recreational fishery resources of the United States. Since procedures for developing Fishery Management Plans and the Plans' roles as regulatory guidelines for U.S. fisheries are important parts of the Act, fishery management is becoming more common throughout the nation. Although managers have developed strategies for establishing optimum yields, the landings data being accumulated by State and Federal agencies are in most instances not adequate for determining catch quotas or catch levels within necessary time frames.

Commercial and recreational catch records of fishes in the United States are collected in various ways and reported by several organizations, including the National Marine Fisheries Service (NMFS), state agencies, the U.S. Department of Agriculture, and foreign countries fishing in the Fisheries Conservation Zone. The data are reported by month, region, gear type, and species, e.g., "Fisheries of the United States, 1982" (NMFS, 1983). These data are necessary for managing our fisheries but are not produced such that catch quotas or levels can be monitored in a timely manner.

Fisheries with large recreational components pose special problems for managers, because real-time estimates of either total catch or total effort and catch per unit of effort (CPUE) must be made to determine closure points. Although many efforts have been made to generate such statistics (NMFS, 1980; McEachron and Matlock, 1983), most researchers agree that estimating totals for recreational fisheries is very costly and difficult and cannot be accomplished within acceptable time frames. Clearly, another approach is needed to manage mixed or recreational fisheries.

In efforts to learn more about obtaining recreational fishery data on a real-time basis, personnel at the NMFS Southeast Fisheries Center's Panama City Laboratory conducted a pilot survey in 1982. This report describes the survey, highlights its results, and illustrates the uses to which long-term CPUE surveys can be put.

Methods

Our pilot survey was designed to determine the efficiency and feasibility of contracting with selected charterboat captains to provide catch and effort data. Charterboat captains were chosen because: 1) They are an easily identified, efficient component of recreational fisheries; 2) their livelihood depends on a high frequency of fishing trips and angling success; and 3) accurately documenting recreational fishing activity is in the captains' best interests. In February 1982, nine captains were selected from five ports along the south Atlantic and Gulf of Mexico coasts (Fig. 1). These ports were selected to represent the variety of recreational hook-and-line catch and effort within the survey area.

The survey began on 28 March and ended on 30 November in all areas except Key West, Fla., where the survey was continued through 31 December. The collected data contained dates, fishing zones, fishing methods, fishing hours, and numbers of each species that were caught. Fishing zones were recorded as 1) estuarine or bay waters, 2) oceanic waters less than 10 fathoms, or 3) oceanic waters greater than 10 fathoms (Fig. 1). If more than one zone was fished, captains recorded all pertinent numbers. When logs were returned to the Panama City Laboratory, fishing zones were coded as follows: Fishing zone 1—estuarine or bay areas; fishing zone 2—oceanic waters less than 10 fathoms; fishing zone 3—oceanic waters greater than 10

The authors are with the Panama City Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407-7499.

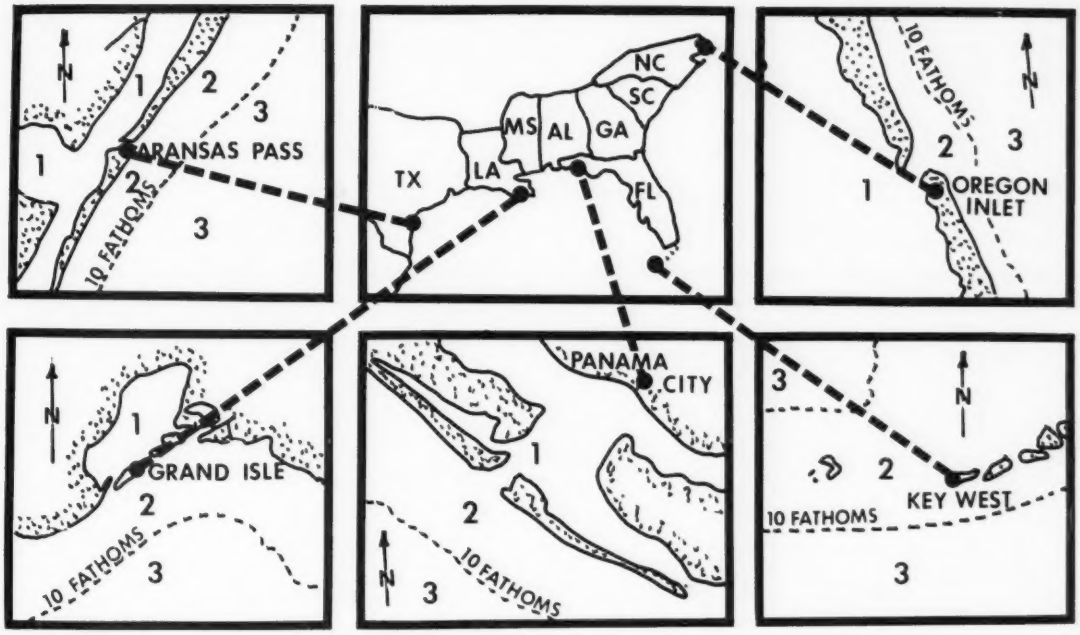


Figure 1.—1982 charterboat sampling ports showing 1) estuarine zone, 2) oceanic zone less than 10 fathoms, and 3) oceanic zone greater than 10 fathoms.

Table 1.—Total fishing hours by area, fishing zone, and method of fishing during the 1982 charterboat survey off the southeastern United States.

	Fishing zones					
	1	2	3	4	6	
Region	Estuarine	Oceanic (< 10 fm)	Oceanic (> 10 fm)	Est. & oceanic (< 10 fm)	Oceanic (all depths)	Total
	Hours trolling and bottom fishing ( )					
North Carolina	4.0	84.5	1,280.0		19.5	1,368.0
South Carolina		95.0 (23.5)	1,039.5 (34.0)		239.5	1,374.0 (57.5)
Northwest Florida	59.5	289.5	60.5	141.5	25.5	576.5
Louisiana	2.0	7.5	282.0 (775.5)		11.0 (10.0)	302.5 (785.5)
South Texas	6.0 (68.5)	550.0 (8.0)	129.5		85.5	771.0 (76.5)
Total	71.5 (68.5)	1,006.5 (31.5)	2,791.5 (809.5)	141.5	381.0 (10.0)	4,392.0 (919.5)

fathoms; fishing zone 4—combination of fishing in zones 1 and 2; fishing zone 5—combination of fishing in zones 1 and 3; fishing zone 6—combination of fishing in zones 2 and 3; fishing zone 7—combination of fishing in zones 1, 2, and 3. Fishing methods were categorized as "trolling," during which lines were fished at any depth while the vessel was moving under its own power, or "bottomfishing," which included all other effort. No running times were included in the "fishing hours." Catches of all species were reported.

Since each log form contained data from a fishing week (Sunday through Saturday), captains usually mailed the postage-paid self-addressed log forms early in the next week. Within 10 days after the fishing week in question, reponse rate was about 70 percent; within 20 days above 80 percent; and by 30 days over 90 percent.

Results

In 1982, we obtained 90.4 percent of the catch and effort records for which we originally contracted. Eight of the nine captains that contracted with us kept records throughout the survey; one captain resigned from the survey after 6 months. Survey respondents reported fishing activity on 1,043 of the 2,324 potential boat-fishing days and logged 5,311.5 boat-fishing hours (Table 1).

Table 2.—Number of each species or species group caught by trolling in relation to area a

Common name	Scientific name	North Carolina				South Florid	
		1	2	3	C	2	3
Dolphin	*Coryphaena hippurus*			5,238		35	2,229
Bluefish	*Pomatomus saltatrix*	250	1,045	944	71		
King mackerel	*Scomberomorus cavalla*			475		34	89
Spanish mackerel	*Scomberomorus maculatus*					1	
Little tunny	*Euthynnus alletteratus*			262		31	86
Blue runner	*Caranx crysos*					1	2
Yellowfin tuna	*Thunnus albacares*			1,078			1
Great barracuda	*Sphyraena barracuda*					185	213
Atlantic bonito	*Sarda sarda*			26		1	81
Red drum	*Sciaenops ocellatus*						
Crevalle jack	*Caranx hippos*						4
Yellowtail snapper	*Ocyurus chrysurus*					36	26
Wahoo	*Acanthocybium solanderi*			52		2	43
Cero	*Scomberomorus regalis*					30	63
Skipjack tuna	*Euthynnus pelamis*			114			1
Greater amberjack	*Seriola dumerili*						10
Blackfin tuna	*Thunnus atlanticus*			46		3	16
Cobia	*Rachycentron canadum*						
White marlin	*Tetrapturus albidus*			70			1
Ladyfish	*Elops saurus*						
Black grouper	*Mycteroperca bonaci*					6	7
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*						
Sailfish	*Istiophorus platypterus*			3		1	28
Blacktip shark	*Carcharhinus limbatus*						1
Red snapper	*Lutjanus campechanus*						
Unident. sharks	*Squaliformes*			1			6
Bluefin tuna	*Thunnus thynnus*			20			
Gray triggerfish	*Balistes capriscus*			1			
Albacore	*Thunnus alalunga*		5	4	9		
Hutton snapper	*Lutjanus analis*					4	3
Blue marlin	*Makaira nigricans*			10			4
Spinner shark	*Carcharhinus brevipinna*						
Tripletail	*Lobotes surinamensis*						4
Almaco jack	*Seriola rivoliana*						
Silky shark	*Carcharhinus falciformis*						6
Red grouper	*Epinephelus morio*						
Bar jack	*Caranx ruber*					1	
Gag	*Mycteroperca microlepis*					2	
Horse-eye jack	*Caranx latus*						
Seatrout	*Cynoscion* sp.						
Lesser amberjack	*Seriola fasciata*						
Gray snapper	*Lutjanus griseus*						1
Hammerhead shark	*Sphyrna* sp.			2			
Mako	*Isrus* sp.		1	1			
Rainbow runner	*Elagatis bipinnulata*					1	
Dusky shark	*Carcharhinus obscurus*					1	
Unident. triggerfish	Balistidae						
Houndfish	*Tylosurus crocodilus*						
Scamp	*Mycteroperca phenax*						
Spadefish	*Chaetodipterus faber*						
Tarpon	*Megalops atlanticus*						1
Total		250	1,051	8,347	80	375	2,926

[1] 1 = Estuarine, 2 = Oceanic (< 10 fm), 3 = Oceanic (> 10 fm), and C = Combination of 1, 2, and/or 3.

area and fishing zone[1] during the 1982 charterboat survey of the southeastern United States.

Florida		Northwest Florida				Louisiana				South Texas				Total
3	C	1	2	3	C	1	2	3	C	1	2	3	C	Catch
2,229	69		156	21	31			2,779			32	65	11	10,666
		235	1		78		1	51	1		3			2,680
89	24		244	128	41			32			641	217	130	2,055
	1	239	275	1	455	9	15	327	13		393	2	8	1,739
86	13	98	431	6	113		2	162	32		20	1		1,257
2	2	6	406	2	629		1	139	5					1,193
1								12						1,091
213	416				1			10						825
81	12		42	1	74									237
		17				9	43	134	13			1		217
4	7				4		1	65	11		85	1		178
26	110													172
43	2							57						156
63	59													152
1														115
10	1		35	9	10			20			4			89
16	1				1			14	1					82
			2	1	4			8			37	1	19	72
1								1						72
			37		24									61
7	29		8											50
											23	13	10	46
28	6										1			39
1								3			20	8	3	35
											6	22	3	31
6								10			8			25
														20
		1	8	3	5						1			19
														18
3	10													17
4														14
								7					1	8
4								3			1			8
								7						7
6														6
	5													5
	3													4
	1													3
	3													3
										3				3
											2			2
1			1											2
														2
														2
	1													2
	1													2
								2						2
								1						1
			1											1
											1			1
1														1
2,926	776	596	1,647	172	1,470	18	63	3,844	76	3	1,278	331	185	23,488

Of the reported effort, 82.7 percent was spent trolling and 17.3 percent was spent bottomfishing (Table 1). Captains from all regions trolled, but only six of the nine survey captains reported bottomfishing (neither North Carolina (NC) nor the northwest Florida (NWF) captains reported bottomfishing). Evaluation of effort by fishing zone showed that 67.8 percent of the total effort was expended in zone three, 19.5 percent in zone two, 7.4 percent in zone six (combined oceanic waters), and the remainder in zones one and four (combined estuarine and oceanic waters less than 10 fathoms). Most of the regional effort was: NC—93.6 percent trolling in zone three; South Florida (SF)—72.6 percent trolling in zone three; NWF—50.2 percent trolling in zone two; Louisiana (LA)—71.3 percent bottomfishing in zone three; and Texas (TX)—64.9 percent trolling in zone two. Results from all fishing zones were combined throughout the rest of this report.

Fishes of at least 71 species (39,410 individuals) were caught (Tables 2 and 3). Numbers of species were about the same between trolling and bottomfishing. At least 27 species were caught by both methods with about 20 others specific to each method.

Catches per boat hour (CPH) for trolling effort (Table 4) showed dolphin, little tunny, and king mackerel among the top 10 in all regions. Atlantic bonito, bluefish, Spanish mackerel, and wahoo CPH were in the top 10 in three or four regions. Dolphin, the most abundant species in three of the five regions, showed CPH from 0.14 (TX) to 9.19 (LA); king mackerel, actively sought in most regions, supported CPH from 0.11 (SF and LA) to 1.28 (TX).

Bottomfishing was reported from only three regions (Table 5). Highest CPH's in SF were found for snappers, groupers, and amberjack. In LA, dolphin, Atlantic croaker, red snapper, and sand seatrout were dominant. Annual bottomfishing CPH was higher than trolling (CPH in LA for bluefish (0.37 vs. 0.18), blue runner (0.65 vs. 0.48), and king mackerel (0.52 vs. 0.11). In TX, the catch consisted mostly of red snapper.

Table 3.—Number of each species or species group caught by methods other than trolling in relation to area and fishing zone during the 1982 charterboat survey of the southeastern United States.

		Region and zone[1]						
		South Florida		Louisiana		South Texas		Total
Common name	Scientific name	2	3	3	C	1	2	catch
Atlantic croaker	*Micropogonias undulatus*			4,868				4,868
Red snapper	*Lutjanus campechanus*			2,900			106	3,006
Sand seatrout	*Cynoscion arenarius*			2,056				2,056
Dolphin	*Coryphaena hippurus*			1,991				1,991
Unident. seatrout	*Cynoscion* sp.			628		16		644
Blue runner	*Caranx crysos*			495	18			513
Gray triggerfish	*Balistes capriscus*			493				493
King mackerel	*Scomberomorus cavalla*			410				410
Greater amberjack	*Seriola dumerili*	5	101	157	30			293
Bluefish	*Pomatomus saltatrix*			287				287
Blacktip shark	*Carcharhinus limbatus*			162				162
Yellowtail snapper	*Ocyurus chrysurus*	152						152
Red drum	*Sciaenops ocellatus*			69		62		131
Cobia	*Rachycentron canadum*	1		130				131
Little tunny	*Euthynnus alletteratus*			96	6			102
Gafftopsail catfish	*Bagre marinus*			97				97
Pinfish	*Lagodon rhomboides*			92				92
Crevalle jack	*Caranx hippos*			58	1			59
Lane snapper	*Lutjanus synagris*	33		24				57
Almaco jack	*Seriola rivoliana*			36				36
Blackfin tuna	*Thunnus atlanticus*			33	3			36
Gray snapper	*Lutjanus griseus*	15		18				33
Spinner shark	*Carcharhinus brevipinna*			31				31
Red grouper	*Epinephelus morio*	23		7				30
Scamp	*Mycteroperca phenax*			30				30
Spotted seatrout	*Cynoscion nebulosus*					23		23
Gag	*Mycteroperca microlepis*			20				20
Atlantic bonito	*Sarda sarda*		1	15				16
Spanish mackerel	*Scomberomorus maculatus*			14				14
Rainbow runner	*Elagatis bipinnulata*			13				13
Spadefish	*Chaetodipterus faber*			13				13
Great barracuda	*Sphyraena barracuda*	5		5				10
Rock sea bass	*Centropristis philadelphica*			9				9
Unident. sharks	*Squaliformes* sp.			8				8
Yellowfin grouper	*Mycteroperca venenosa*			6				6
Sheepshead	*Archosargus probatocephalus*					6		6
Porgies	Sparidae			6				6
Conger eels	Congridae			5				5
Cusk-eels	Ophidiidae			5				5
Black drum	*Pogonias cromis*			4				4
Lookdown	*Selene vomer*			4				4
Ladyfish	*Elops saurus*			1		3		4
Toadfish	*Opsanus* sp.			4				4
Vermilion snapper	*Rhomboplites aurorubens*			2				2
Warsaw grouper	*Epinephelus nigritus*		1				1	2
Banded rudderfish	*Seriola zonata*			1				1
Flounder	*Paralichthys* sp.			1				1
Hammerhead shark	*Sphyrna* sp.			1				1
Jewfish	*Epinephelus itajara*	1						1
Kingfish	*Menticirrhus* sp.			1				1
Morays	Muraenidae			1				1
Searobins	Triglidae			1				1
Soapfish	*Rypticus* sp.			1				1
Total		235	103	15,309	58	110	107	15,922

[1]1 = Estuarine, 2 = Oceanic (< 10 fm), 3 = Oceanic (> 10 fm), and C = Combination of 1, 2, and/or 3.

Monthly CPH's for each species in each region were computed; the results for each region's five most abundant species caught by trolling are presented in Table 6. Highest CPH's of king mackerel occurred from June through August off TX, from August through October off NWF, in October off NC, and in December off SF. Off LA, the only region where king mackerel was not among the top five, CPH's for this species were low (0.00-0.19) from April through October, but jumped to 0.88 in November. Peak dolphin

CPH (Table 6, Fig. 2) occurred in June off LA (the highest monthly CPH for any species caught by either fishing method), in July off SF and NWF, and in August off NC and TX.

Monthly CPH's for bottomfishing are shown in Table 7. Off SF, yellowtail snapper, the most abundant species, was most abundant during July. Off LA, Atlantic croaker was most abundant from August through October. Off TX, red snapper CPH was highest in August.

Interpretation of Results

Although the survey's data were too limited to support extensive analysis, two results need comment. First, the effort distribution by fishing zone and method is not necessarily representative of the overall charterboat fishery in any region. In the 1982 survey, with each region being represented by only one or two boats, captains' specialties strongly influenced reported effort. For instance, Table 1 shows that trolling was the only fishing method used in NWF. Only one captain from NWF was in the survey and he specialized in trolling for king and Spanish mackerel. Since those species are found primarily in estuarine and near-shore Gulf waters off NWF, his fishing activities usually occur there, too. However, not all NWF charterboat captains are so specialized. Caution must be exercised in generalizing the 1982 survey effort results.

Secondly, the influence of effort classification must not be overlooked, since our definition of fishing method caused some apparently unusual results. In LA, bottomfishing CPH's were higher for several pelagic species than were corresponding trolling CPH's. Most coastal pelagics caught off LA were taken by "fly-lining," in which a live bait was fished on an unweighted line while the boat was tied to an offshore structure. Since such boats were not moving under power, we categorized "fly-lining" as "bottomfishing." Although a more accurate term for our bottomfishing category would be "non-trolling activities," we retained the term that was used on the survey log form. The reader should be aware of this in assessing the 1982 survey results.

Table 4.—The ten most abundant species caught by trolling in each area during the 1982 charterboat survey of the southeastern United States.

Region and species	Number	CPH	Percent w/i region
North Carolina			
Dolphin	5,238	3.83	53.84
Bluefish	2,310	1.69	23.75
Yellowfin tuna	1,078	0.79	11.08
King mackerel	475	0.35	4.88
Little tunny	262	0.19	2.69
White marlin	70	0.05	0.72
Wahoo	52	0.04	0.53
Blackfin tuna	46	0.03	0.47
Atlantic bonito	26	0.02	0.27
Albacore	18	0.01	0.19
	9,575		98.43
South Florida			
Dolphin	2,333	1.70	57.22
Great barracuda	814	0.59	19.97
Yellowtail snapper	172	0.13	4.22
Cero	152	0.11	3.73
King mackerel	147	0.11	3.61
Little tunny	130	0.10	3.19
Atlantic bonito	94	0.07	2.31
Wahoo	47	0.03	1.15
Black grouper	42	0.03	1.03
Sailfish	35	0.03	0.86
	3,966		97.28
Northwest Florida			
Blue runner	1,043	1.81	26.85
Spanish mackerel	970	1.68	24.97
Little tunny	648	1.12	16.68
King mackerel	413	0.72	10.63
Bluefish	314	0.55	8.08
Dolphin	208	0.36	5.35
Atlantic bonito	117	0.20	3.01
Ladyfish	61	0.11	1.57
Greater amberjack	54	0.09	1.39
Red drum	17	0.03	0.44
	3,845		98.97
Louisiana			
Dolphin	2,779	9.19	69.46
Spanish mackerel	364	1.20	9.10
Red drum	199	0.66	4.97
Little tunny	196	0.65	4.90
Blue runner	145	0.48	3.62
Crevalle jack	77	0.25	1.92
Wahoo	57	0.19	1.43
Bluefish	53	0.18	1.32
King mackerel	32	0.11	0.80
Cobia	8	0.03	0.20
	3,910		97.73
South Texas			
King mackerel	988	1.28	54.98
Spanish mackerel	403	0.52	22.43
Dolphin	108	0.14	6.01
Crevalle jack	86	0.11	4.79
Cobia	57	0.07	3.17
Atlantic sharpnose shark	46	0.06	2.56
Red snapper	31	0.04	1.73
Blacktip shark	31	0.04	1.73
Little tunny	21	0.03	1.17
Unident. sharks	8	0.01	0.45
	1,779		99.00

Table 5.—The ten most abundant species caught by methods other than trolling in each region[1] during the 1982 charterboat survey of the southeastern United States.

Region and species	Number	CPH	Percent w/i region
South Florida			
Yellowtail snapper	152	2.64	44.97
Greater amberjack	106	1.84	31.36
Lane snapper	33	0.57	9.76
Red grouper	23	0.40	6.80
Gray snapper	15	0.26	4.44
Great barracuda	5	0.09	1.48
Cobia	1	0.02	0.30
Atlantic bonito	1	0.02	0.30
Warsaw grouper	1	0.02	0.30
Jewfish	1	0.02	0.30
	338		100.00
Louisiana			
Atlantic croaker	4,868	6.20	34.02
Red snapper	2,900	3.69	20.26
Sand seatrout	2,056	2.62	14.36
Dolphin	1,991	2.54	13.91
Seatrout	628	0.80	4.39
Blue runner	513	0.65	3.59
Gray triggerfish	493	0.63	3.45
King mackerel	410	0.52	2.87
Bluefish	287	0.37	2.01
Blacktip shark	162	0.21	1.13
	14,308		99.99
South Texas			
Red snapper	106	1.39	49.76
Red drum	62	0.81	29.10
Spotted seatrout	23	0.30	10.79
Unident. seatrout	16	0.21	7.51
Sheepshead	6	0.08	2.81
Ladyfish	3	0.04	1.38
Warsaw grouper	1	0.01	0.46
	217		100.00

[1]No fishing hours for methods other than trolling were logged in North Carolina or in northwest Florida.

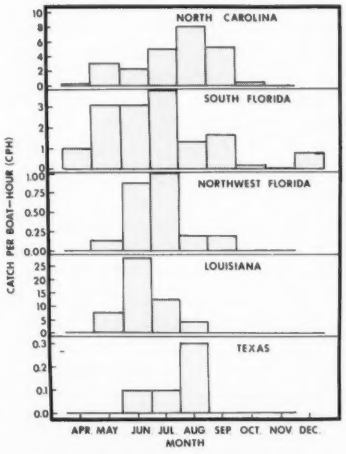


Figure 2.—Monthly catch per boat hour of dolphin caught by trolling in each region during 1982 charterboat survey of southeastern United States.

Discussion

The main success of the 1982 survey was its unusual efficiency in

Table 6.—Mean catch per boat-hour by month for the five most abundant species caught by trolling within each region during the 1982 charterboat survey of the southeastern United States.

Region and species	Mean catch/boat-hour								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North Carolina									
Dolphin	0.03	3.11	2.30	5.05	7.92	5.55	3.35	—[1]	—
Bluefish	10.55	3.92	0.06	0.20	0.00	0.00	0.18	—	—
Yellowfin tuna	0.01	0.03	2.44	0.35	0.28	0.62	0.53	—	—
King mackerel	0.04	0.31	0.08	0.02	0.02	0.04	4.25	—	—
Little tunny	1.27	0.01	0.02	0.13	0.00	0.04	0.75	—	—
South Florida									
Dolphin	0.97	3.14	3.18	4.19	1.26	1.55	0.08	0.41	1.00
Great barracuda	0.30	0.07	0.16	0.19	0.95	1.11	0.87	1.48	0.53
Yellowtail snapper	0.20	0.00	0.01	0.03	0.04	0.15	0.41	0.18	0.00
Cero	0.14	0.00	0.00	0.03	0.17	0.06	0.06	0.23	0.39
King mackerel	0.04	0.00	0.00	0.01	0.20	0.02	0.00	0.06	0.71
Northwest Florida									
Blue runner	0.52	5.60	4.03	0.31	0.32	0.62	0.28	—	—
Spanish mackerel	2.54	0.49	0.04	0.21	2.28	4.97	0.24	—	—
Little tunny	0.05	0.80	1.62	1.91	1.88	0.61	0.32	—	—
King mackerel	0.00	0.02	0.47	0.22	1.18	1.45	1.11	—	—
Bluefish	5.53	0.87	0.03	0.00	0.00	0.00	0.05	—	—
Louisiana									
Dolphin	0.00	7.28	29.51	10.92	2.36	0.50	0.00	0.00	—
Spanish mackerel	0.00	0.49	1.07	0.00	3.49	2.36	0.00	0.00	—
Red drum	0.00	0.00	0.00	0.00	2.38	1.36	0.00	0.00	—
Little tunny	0.00	0.82	0.86	0.18	0.80	1.43	2.00	0.50	—
Blue runner	0.00	1.15	1.07	0.19	0.56	0.21	0.00	0.63	—
South Texas									
King mackerel	0.17	0.20	1.16	1.67	1.25	0.14	—	—	—
Spanish mackerel	0.00	0.00	0.00	0.00	0.04	11.21	—	—	—
Dolphin	0.00	0.00	0.07	0.11	0.27	0.00	—	—	—
Crevalle jack	0.17	0.72	0.07	0.03	0.16	0.00	—	—	—
Cobia	0.00	0.00	0.17	0.08	0.02	0.03	—	—	—

[1]Dash indicates zero fishing effort.

Table 7.—Mean catch per boat-hour by month for the five most abundant species caught by methods other than trolling in each region[1] during the 1982 charterboat survey of the southeastern United States.

Region and species	Mean catch/boat-hour								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
South Florida									
Yellowtail snapper	0.00	0.00	0.00	18.91	0.00	3.00	—[2]	—	—
Greater amberjack	3.11	3.67	2.00	0.00	1.33	0.00	—	—	—
Lane snapper	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—
Red grouper	0.00	0.00	0.00	0.00	0.00	1.44	—	—	—
Great barracuda	0.00	0.00	0.00	0.00	0.00	0.31	—	—	—
Louisiana									
Atlantic croaker	0.97	2.36	1.73	4.31	11.84	14.77	9.44	3.78	0.00
Red snapper	5.70	4.17	4.05	5.40	3.15	3.16	2.98	2.41	2.40
Sand seatrout	0.42	1.11	0.13	0.21	0.22	0.47	3.79	13.60	0.00
Dolphin	0.00	1.52	13.86	0.01	0.00	0.00	0.00	0.00	0.00
Unident. seatrout	0.00	0.00	0.00	0.00	0.00	0.00	2.36	3.42	0.00
South Texas									
Red snapper	0.00	0.61	0.00	—	23.75	0.00	0.00	—	—
Red drum	0.89	0.72	0.56	—	0.00	1.08	0.94	—	—
Spotted seatrout	0.11	0.00	0.00	—	0.00	1.83	0.00	—	—
Unident. seatrout	0.00	0.33	1.11	—	0.00	0.00	0.00	—	—
Sheepshead	0.00	0.11	0.00	—	0.00	0.08	0.12	—	—

[1]No hours were logged in North Carolina or in northwest Florida.
[2]Dash indicates zero fishing effort.

collecting and reporting recreational fishery data. Our response rate (90.4 percent) is substantially higher than others reported for mailed questionnaires or log forms, including Browder et al. (1981), 31.25 percent; Rose and Hassler (1969), 20 percent and 39 percent in 1961 and 1962, respectively; and Brusher et al. (1978), 58.2 percent. Historically, response to mailed questionnaires has been poor enough that Rose and Hassler (1969) noted, that "postcard surveys should probably be based on an expected return of no greater than 33 percent." The obvious difference between our study and those cited was the contracting. Respondents seemed strongly influenced by a signed agreement and monetary consideration for their efforts. No other marine recreational fishing survey with which we are familiar has attempted to produce results in "real time," and many (Ellis et al., 1958; Irby, 1974; Ditton et al., 1978; McEachron and Matlock, 1983; Manooch and Laws, 1979; Manooch et al., 1981; and Rose and Hassler, 1969) only published annual results. Our survey allows us to provide reasonably complete CPUE reports for any calendar week within approximately 2 weeks of the end of that week, making it the fastest recreational fishery statistics reporting mechanism with which we are familiar.

Our 1982 survey procedures have been continued in 1983 (Fig. 3) and have enabled us to produce CPUE reports in our laboratory within two days of receiving captains' log forms. We typically receive 70-80 percent of the forms from our frame of 100 captains within 10 days after each fishing week, so computer-generated CPUE reports can be produced within 2 weeks of fishing activity. Reports issued from our laboratory by the tenth of each month usually include 72 percent of the expected responses for the previous fishing month.

Since we presented few analytical treatments of the 1982 survey, examples of other CPUE analyses will help illustrate the uses to which charterboat CPUE data may be put. Many applications appeared in Fable et al. (1981), whose Figures 3, 4, 5, and 10 are reproduced in this paper (Fig. 4-7). The mean catch per hour (Fig. 4) can be modified to show values for a single species through time and space, or to show relative species abundance by location (Fig.

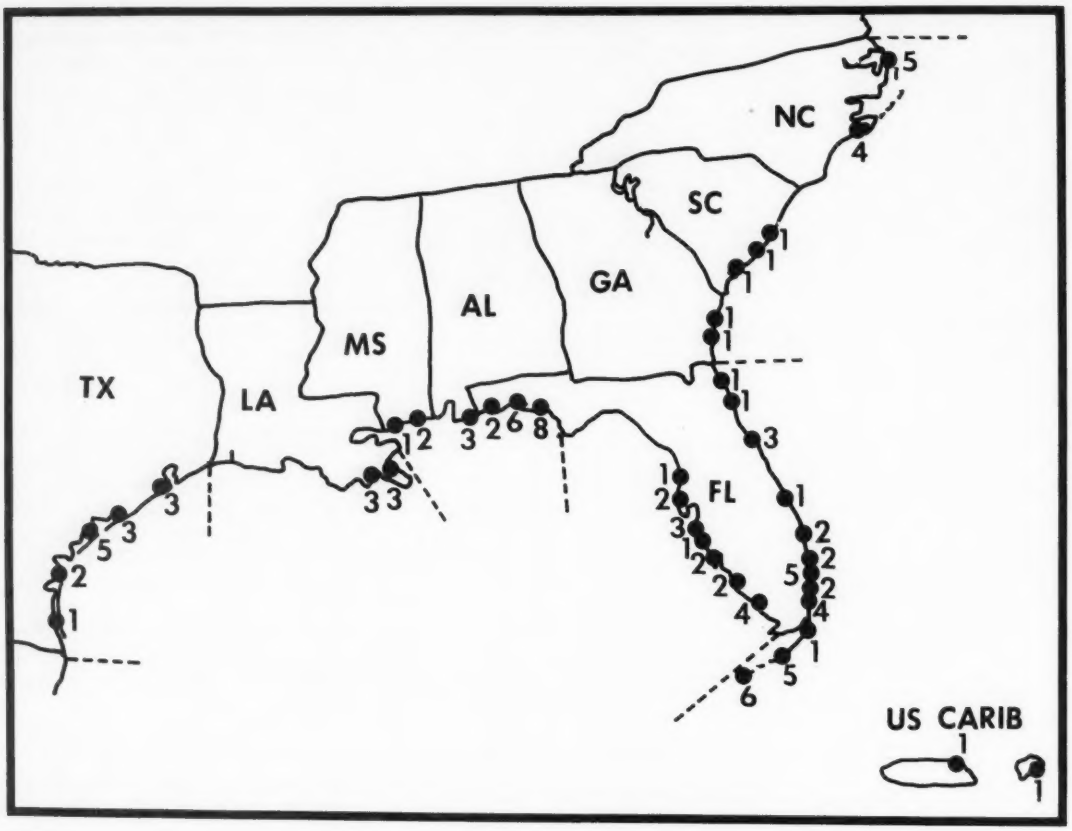


Figure 3.—1983 charterboat survey ports showing initial number of contracted vessels in each port.

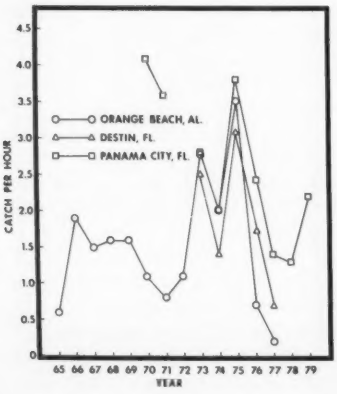


Figure 4.—King mackerel catch per hour from three areas of the northeastern Gulf of Mexico (from Fable et al., 1981, Fig. 3).

5). Monthly CPUE through time is illustrated in Figure 6, which resembles our Figure 2 but presents data by year rather than by location. Finally, environmental effects on CPUE can be investigated, as in Figure 7.

Perhaps the most important potential use of charterboat CPUE data is estimating the relative abundance of species through time and space. It is very difficult to obtain rigorous recreational fishery indicators for management. Our success with the 1982 survey shows that charterboat CPUE is obtainable. The management question is, "How reliably does charter-

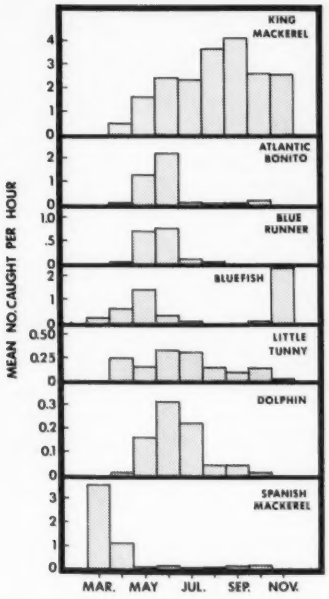


Figure 5.—Average monthly catch per hour of the seven most abundant species caught in Panama City, Fla. (from Fable et al., 1981, Fig. 4).

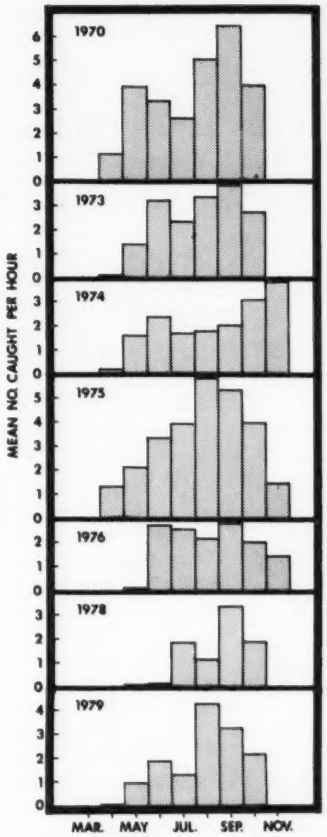


Figure 6.—Average montly catch per hour of king mackerel by year in Panama City, Fla. (from Fable et al., 1981, Fig. 5).

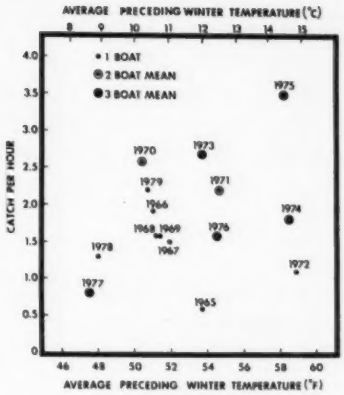


Figure 7.—King mackerel catch per hour plotted against preceding winter average air temperature (from Fable et al., 1981, Fig. 10).

boat CPUE indicate relative species abundance?" Further research and planning are underway to determine the best ways in which to assess abundance from CPUE data. Possible alternatives include surveys of relative effort through time and space, thus establishing an indexing factor for adjusting raw CPUE values, and investigations of "replacement of mean C/f [CPUE] with a less biased index of abundance" (Bannerot, 1982). However, without fundamental data collected in restricted spatio-temporal increments, no abundance estimates are possible. We believe that contracting with charterboat captains of the marine fishery constituency provides a key to the proper representation of recreational fishing interests and a foundation for effective, equitable management decisions.

Literature Cited

Bannerot, S. 1982. Incorporating frequency distributions of catch per unit effort into recreational and other fishery statistics. M.S. thesis, Univ. Miami, 41 p.

Browder, J. A., and J. C. Davis, and E. Sullivan. 1981. Paying passenger recreational fisheries of the Florida Gulf coast and Keys. Mar. Fish. Rev. 43(8):12-20.

Brusher, H. A., L. Trent, and M. L. Williams. 1978. Recreational fishing for king mackerel in Bay County, Florida, during 1975. *In* B. Austin et al. (editors), Mackerel workshop Report, p. 120-142. Univ. Miami Sea Grant Spec. Rep. 14.

Ditton, R. B., R. N. Jarman, and S. A. Woods. 1978. An analysis of the charter boat fishing industry on the Texas Gulf coast. Mar. Fish. Rev. 40(8):1-7.

Ellis, R. W., A. Rosen, and A. W. Moffett. 1958. A survey of the number of anglers and of their fishing effort and expenditures in the coastal recreational fishing of Florida. Fla. State Board Conserv. Tech. Ser. 24, 1958 (May), 50 p.

Fable, W. A., Jr., H. A. Brusher, L. Trent, and J. Finnegan, Jr. 1981. Possible temperature effects on charter boat catches of king mackerel and other coastal pelagic species in northwest Florida. Mar. Fish. Rev. 43(8):21-26.

Irby, E. W., Jr. 1974. A fishing survey of Choctawhatchee Bay and adjacent Gulf of Mexico waters. Fla. Mar. Res. Publ. 2, 26 p.

Manooch, C. S., III, L. E. Abbas, and J. L. Ross. 1981. A biological and economic analysis of the North Carolina charter boat fishery. Mar. Fish. Rev. 43(8):1-11.

Monooch, C. S., III, and S. T. Laws. 1979. Survey of the charter boat troll fishery in North Carolina, 1977. Mar. Fish. Rev. 41(4):15-27.

McEachron, L. W., and G. C. Matlock. 1983. An estimate of harvest by the Texas charter boat fishery. Mar. Fish. Rev. 45(1):11-17.

NMFS. 1980. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1979. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 8063, 139 p.

NMFS. 1983. Fisheries of the United States, 1982. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 8300, 117 p.

Rose, C. D., and W. W. Hassler. 1969. Application of survey techniques to the dolphin, *Coryphaena hippurus*, fishery of North Carolina. Trans. Am. Fish. Soc. 98:94-103.

The Incidental Capture of Sea Turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese Tuna Longline Fleet, 1978-81

W. N. WITZELL

ABSTRACT—*The incidental capture of sea turtles by the Japanese tuna longline fleet in the Atlantic U.S. Fishery Conservation Zone is assessed for the years 1978 through 1981. The total estimated turtle catch is derived by multiplying the observed catch-per-unit-effort and the total reported effort from the Japanese fishing logbooks. The observed catch-per-unit-effort, survivability, and estimated total turtle captures varied considerably between the Atlantic Ocean and Gulf of Mexico. An estimated 330 turtles were captured, 126 in the Atlantic and 204 in the Gulf of Mexico. The central Gulf of Mexico may be major habitat for leatherback turtles in the western central Atlantic Ocean.*

Introduction

The incidental capture of threatened or endangered species of sea turtles by commercial fishing fleets in U.S. waters needs to be adequately addressed. Although several studies have been conducted concerning the incidental trawl catch of turtles by the shrimping fleet, the published information is limited (Hillestad et al., 1978; 1981). The quantification of the incidental capture rate of turtles by each fishery is necessary when formulating conservation and management strategies as mandated by the Endangered Species Act of 1973 and the Magnuson Fishery Conservation and Management Act of 1976. Analyzed in this paper is the incidental capture of sea turtles by the Japanese tuna longline fleet inside the Atlantic U.S. Fishery Conservation Zone.

Materials and Methods

All foreign vessels wishing to fish inside the U.S. 200 n.mi. Fishery Conservation Zone (FCZ) must obtain a permit, maintain accurate fishing records showing amount and location of catch and fishing effort, release all nontarget species whether alive or dead, and allow U.S. observers on board vessels.

The Japanese tuna longline is fished from vessels ranging in length from 50 to 70 m. A mainline, 100-135 km long, is suspended horizontally from the surface by a series of floats (Fig. 1). Suspended vertically from the mainline is a series of branchlines, 15-25 m long, each line terminating with a hook baited with mackerel, saury, or squid. The longline is set between 0000 h and 0800 h from a moving vessel and hauled back from 1200 h to 0000 h. The fishery is dynamic, and changes in gear and methods frequently occur, depending on geographic location and target species fished. The Japanese tuna

W. N. Witzell is with the Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149.

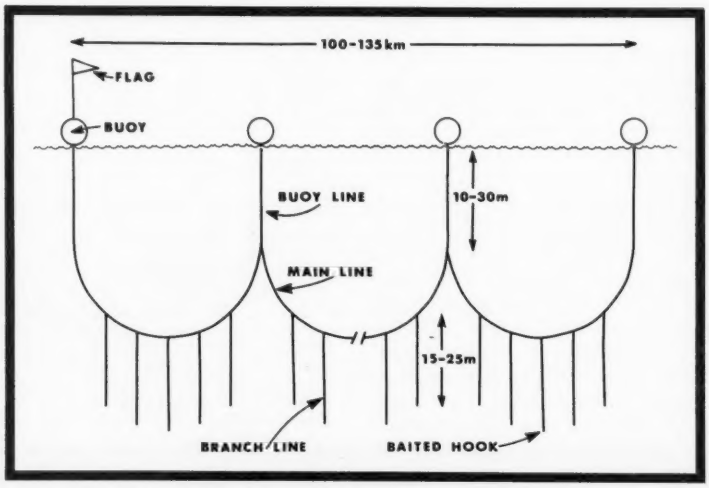


Figure 1.—Schematic diagram of a Japanese tuna longline in the fishing position, illustrating major structural components.

Table 1.—Total number of sea turtles observed captured in the Atlantic U.S. Fishery Conservation Zone by the Japanese tuna longline fleet, 1978-81.

Area and species	Total turtles	No. of live turtles	Percent alive
Atlantic			
Unknown turtles	25	17	68.0
Leatherback turtles	2	2	100.0
Total	27	19	70.4
Gulf of Mexico			
Unknown turtles	18	17	94.4
Leatherback turtles	12	11	91.6
Total	30	28	93.3

Table 2.—The observed and estimated total numbers of sea turtles incidentally captured in the Atlantic U.S. Fishery Conservation Zone by the Japanese tuna longline fleet, 1978-81.

Area	Total observed hooks	Total observed turtles	Number turtles per 10,000 hooks	Total reported hooks	Estimated number turtles captured
Atlantic	3,651,434	27	0.07388	17,031,122	126
Gulf of Mexico	1,662,273	30	0.18047	11,329,069	204
Total	5,313,707	57		28,360,191	330

longline fishery in the Gulf of Mexico has been described in detail by Lopez et al. (1979).

The data used to calculate the incidental catch of sea turtles are from the U.S. observer files and from the reported Japanese fishing logbooks; both data bases are maintained by the National Marine Fisheries Service's Southeast Fisheries Center. The incidental catch information was opportunistically collected during a tuna survey and therefore does not provide a comprehensive data base, temporally or spatially. It is felt that rigorous statistical analysis of the data would not be possible. Because observers were not on board all the Japanese tuna vessels, the total incidental turtle catch is derived by multiplying the observed turtle catch-per-unit-effort and the total reported effort from the Japanese fishing logbooks. Effort is expressed as 10,000 hooks fished. For this report, the U.S. Atlantic Ocean FCZ is divided into two subareas: Atlantic (off the eastern U.S. coast) and the Gulf of Mexico.

The turtles are arranged into two species groups, 1) unidentified and 2) leatherback, *Dermochelys coriacea*. Observers were often unable to identify turtles in the water from the deck of a moving vessel; the unidentified turtles are either green, *Chelonia mydas*; Kemp's ridley, *Lepidochelys kempi*; or loggerhead, *Caretta caretta*. Most unidentified turtles are probably loggerheads, however, because they are the most abundant species inhabiting the U.S. Atlantic Ocean FCZ (Carr, 1952; Ernst and Barbour, 1972; Rebel, 1974; Bacon, 1981; Carr et al., 1982).

Results and Discussions

The turtles incidentally captured on tuna longlines were either hooked in the mouth, hooked in the flipper-shoulder area, or tangled in the branchline. The often piscivorous loggerhead turtles are more likely than the other species to eat the bait and become hooked in the mouth. The leatherback feeds almost exclusively on Scyphomedusidae (Pritchard, 1971), probably will not take a baited hook, but is likely to become hooked in the flipper-shoulder area or tangled in the branchline. The large flipper span causes the leatherback to become easily entangled in branchlines and individuals have been known to continue swimming while hopelessly tangled in crab pot lines (Rudloe, 1979). The turtles could be captured while feeding or cruising at the surface when the longline is being set or hauled, or even when the longline is fishing between 25 and 55 m depth.

The total number of turtles observed captured in the Atlantic and Gulf of Mexico were evenly distributed—Atlantic, 27; Gulf, 30 (Table 1)—but the total percentage of turtles observed alive varied between these areas, 70.4 and 93.3 percent, respectively. This is reflected by the survivorship of the unknown turtles in the Atlantic, 68.0 percent, as opposed to 94.3 percent for those unknown turtles in the Gulf of Mexico. This difference in survival possibly reflects different fishing strategies used in the Atlantic Ocean and Gulf of Mexico. Also, the Atlantic longline fishery is frequently a winter fishery, and possibly the captured turtles may experience detrimental thermal shock.

The observed catch-per-unit-effort of sea turtles (Table 2) also varies between the Atlantic and Gulf of Mexico, 0.7388 and 0.18047, respectively. Despite a lower total fishing effort, there is a much greater chance of incidentally capturing sea turtles on a tuna longline in the Gulf of Mexico than in the Atlantic. However, the total estimated number of turtles incidentally captured is fairly small, 330, considering the enormity of the total fishing effort. Most of the turtles were captured in January through March in the Gulf of Mexico, and September through January in the Atlantic. These are months with the greatest fishing effort, and therefore, the data do not accurately reflect seasonal turtle abundance.

The geographic distribution of the majority of incidentally captured turtles (Fig. 2) indicates the concentration of fishing effort. The Atlantic longline effort is generally farther offshore in winter than where the usually large summer concentrations of sea turtles are normally found[1].

An interesting aspect of the Japanese longline data is the relatively

[1]Witzell, W. N., and T. Azarovitz. Relative abundance, thermal, and geographic distribution of sea turtles and hammerhead sharks off the Atlantic coast of the United States. Manuscr. in prep.

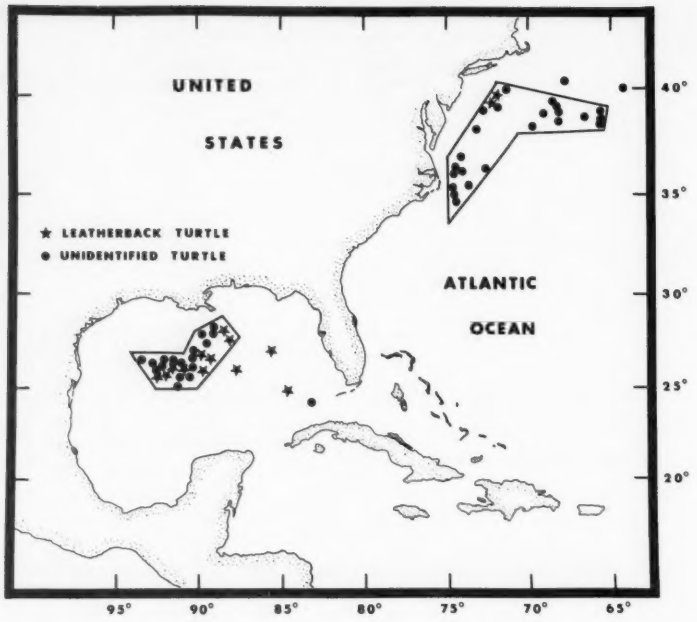


Figure 2.—Locations of incidentally captured sea turtles by the Japanese tuna longline fleet in the Atlantic U.S. Fishery Conservation Zone from 1978 through 1981: The total Japanese longline effort inside the polygons by Atlantic (56.1 percent) and Gulf of Mexico. (59.8 percent).

large numbers of leatherback turtles captured in the Gulf of Mexico. Concentrations of leatherbacks have previously been reported in the Gulf (Leary, 1957; Marquez, 1976), and post-nesting leatherbacks tagged in the Guianas (northeastern South America) have been recovered in the Gulf (Pritchard, 1976). This indicates that the central Gulf of Mexico may be a major habitat for leatherbacks in the western central Atlantic Ocean.

Literature Cited

Bacon, P. 1981. The status of sea turtles stocks management in the western central Atlantic. WECAF Stud. 7:1-38.

Carr, A. 1952. Handbook of turtles. Comstock Publ. Assoc., Ithaca, N.Y., 542 p.

_____, A. Meylan, J. Mortimer, K. Bjorndal, and T. Carr. 1982. Surveys of sea turtle populations and habitats in the western Atlantic. NOAA Tech. Memo. NMFS-SEFC-91, 82 p.

Ernst, C. H., and R. W. Barbour. 1972. Turtles of the United States. Univ. Press Kentucky, Lexington, 342 p.

Hillestad, H., J. Richardson, and G. Williamson. 1978. Incidental capture of sea turtles by shrimp trawlermen in Georgia. Presented at 32nd Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Hot Springs, Virginia. November 5-8, 1978, 32:167-178.

_____, _____, C. McVea, Jr., and J. M. Watson, Jr. 1981. Worldwide incidental capture of sea turtles. *In* K. Bjorndal (editor), Biology and conservation of sea turtles, p. 489-495. Smithson. Inst. Press, Washington, D.C.

Leary, T. R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea coriacea*, on the Texas coast. Copeia 1957:232.

Lopez, A. M., D. B. McClellan, A. R. Bertolino, and M. D. Lange. 1979. The Japanese longline fishery in the Gulf of Mexico, 1978. Mar. Fish. Rev. 41(10):23-28.

Marquez, R. 1976. Estado actual de la pesqueria de tortugas marinas en Mexico, 1974. Ser. Inf. Pesq., Inst. Nac. Pesca, Mexico. 46:1-27.

Pritchard, P. 1971. The leatherback or leathery turtle, *Dermochelys coriacea*. IUCN Monogr. 1, 39 p.

_____. 1976. Post-nesting movements of marine turtles (Cheloniidae and Dermochelyidae) tagged in the Guianas. Copeia 1976:749-754.

Rebel, T. 1974. Sea turtles and the turtle industry of the West Indies, Florida, and the Gulf of Mexico. Univ. Miami Press, Miami.

Rudloe, J. 1979. The time of the turtle. Alfred A. Knopf, N.Y., 273 p.

Encounters of Hawaiian Monk Seals With Fishing Gear at Lisianski Island, 1982

JOHN R. HENDERSON

Introduction

Interactions of marine mammals with various fisheries are documented for many species (Mate, 1980; Beverton, 1982; Contos, 1982), though studies have generally emphasized direct interactions which economically impact a fishery, take considerable numbers of marine mammals, and have high public visibility. Less apparent interactions, such as entanglement in lost or abandoned fishing gear, are more difficult to assess, yet may significantly impact some marine mammal species.

Northern fur seals, *Callorhinus ursinus*, have been observed entangled in net debris on shore and at sea (Fiscus and Kozloff[1]; Jones[2]; Scordino and Fisher[3]), and such entanglements may be a source of significant mortality for the species (Fowler, 1982). Collars of rope and plastic strapping have been reported on Cape fur seals, *Arctocephalus pusillus* (Shaughnessy, 1980), and Antarctic fur seals, *A. gazella* (Bonner and McCann, 1982). Hawaiian monk seals, *Monachus schauinslandi*, are also known to become entangled in fishing gear and other synthetic debris. Monk seals with distinctive, garrote scars have been observed, as have animals bearing net fragments and debris (Balazs, 1979; Kenyon, 1980; Gilmartin[4]). A weaned monk seal pup at French Frigate Shoals was found entangled in, and immobilized by, a piece of fishing net to the extent that drowning would likely have resulted had the animal not been freed (Andre and Ittner, 1980).

Fragments of lost or discarded fishing gear regularly wash ashore at all of the Northwestern Hawaiian Islands (NWHI). At Lisianski Island this occurs predominantly on the east (windward) side of the island and the debris includes net fragments, tangles of rope and line (some of which may be mooring line), and assorted glass and plastic floats. In 1978, Fiscus et al.[5] counted 18 pieces of netting at Lisianski which they considered could entangle a seal. Net fragments and tangles of line also foul on the reefs which extend approximately 100 m offshore on the north and east sides of the island, and remain partially submerged in the shallow (<5 m) water. The size of these fragments ranges from small (<1 m^2) pieces to virtually entire nets weighing over 100 kg. Many of these pieces have been identified as originated from Japanese trawls and gill nets (footnote 5).

From March to September 1982, a study was conducted at Lisianski Island to assess the effect of tagging on the behavior of weaned pups. Methods included individually marking all pups. During the course of this study, seals were observed to encounter fishing gear. These observations are reported here.

Observations

Presence and Accumulation of Net Debris

Those net fragments on the island which were deemed hazardous to monk seals were sampled and inventoried early in the season, and such debris which accumulated throughout the field season was similarly monitored. Assessment of the hazard to seals was subjective; criteria included size of the fragment and presence of loops or holes large enough to encircle the head of the seal. Fifty-two net fragments which had been present an unknown time were counted and 21 fragments washed ashore during the 6 months in which field personnel were on the island.

Inventory of debris included recording the size, location, color, and type of material. Samples were taken

[1]Fiscus, C. H., and P. Kozloff. 1972. Fur seals and fish netting. Appendix E in fur seal investigations, p. 124-132. Natl. Mar. Mammal Lab., Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98112.

[2]Jones, L. L. 1982. Incidental take of northern fur seals in Japanese gillnets in the North Pacific Ocean in 1981. Background paper submitted to the 25th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, Ottawa, 16 p.

[3]Scordino, J., and R. Fisher. 1983. Investigations on fur seal entanglement in net fragments, plastic bands and other debris in 1981 and 1982, St. Paul Island, Alaska. Background paper submitted to the 26th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, held on March 28-April 8, 1983 in Washington, D.C., 33 p. + appendix tables and figures.

[4]W. G. Gilmartin, pers. commun., Honolulu Laboratory, Southwest Fish Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, October 1981.

[5]Fiscus, C. H., A. M. Johnson, and K. W. Kenyon. 1978. Hawaiian monk seal (*Monachus schauinslandi*) survey of the Northwestern (Leeward) Hawaiian Islands. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98112. Proc. Rep., 27 p.

John R. Henderson is with the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 3830, Honolulu, HI 96812.

for subsequent determination of twine and mesh sizes.

Seals Lying on Nets

Seals of all ages often hauled out atop or adjacent to piles of net and line which were high on the beach. No records of this behavoir were maintained, though the behavior was particularly evident among molting individuals who apparently seek objects against which they can roll or rub to facilitate sloughing off old pelage.

Pups Investigating Net Fragments and Flotsam

Five weaned pups, none of which was involved in the entanglement incidents described below, were observed investigating floating net fragments. The pups swam into and around the fragments, often surfacing with mesh covering their head and neck. A sixth weaned pup was observed investigating a large net fragment which was fouled on a rock ledge. Although no entanglement occurred during any of these incidents, encounters such as these could easily result in entanglement if holes large enough to accommodate a head or flipper were present in the fragment.

Weaned pups were also frequently observed nuzzling and investigating plastic and glass floats and other flotsam, often mouthing various objects, including shards of broken glass floats. No injuries from these incidents were noticed. One pup inserted its muzzle into a 7 cm diameter plastic ring which remained tightly encircling the seal's snout for 24 hours before it was removed by field personnel.

Entanglements

Incident One

Soon after arrival at Lisianski on 17 March, field personnel observed a large mass of net approximately 25 m offshore on the east side of the island. Subsequent inspection of the net on 8 April showed that it was fouled on coral rubble in water 3-4 m deep, and the bulk of the net mass was floating. A 43 cm green sea turtle *Chelonia mydas*, and a small ulua, *Caranx* sp. entangled in the net were released.

At 1430 hours on 22 April a weaned male pup was found entangled in the same net. The pup's head and left foreflipper were inserted through a hole in the mesh, and five to six strands encircled the neck and flipper. The pup was lying atop the net mass and not in immediate danger of drowning, but it was so firmly entangled that escape was unlikely and it probably would have starved had it not been released. The net was dragged ashore. It formed a pile 1.5 m high, 2 m in diameter, and probably weighed over 100 kg. The twine was gray polypropylene 2 mm in diameter; the stretched mesh size was 9 cm.

Incident Two

At 0830 hours on 6 May, a weaned pup was observed ashore on the north end of the island with a piece of net around its chest. The net fragment did not impede the seal's movements, but was tightly constricted about the chest, forming a 1-2 cm deep depression around the animal. The net would likely have eventually slipped off due to postweaning weight loss and the attendant reduction in girth. Nonetheless, infection and necrosis of the constricted tissue surrounding the constriction might also have occurred, or the net might have fouled on a piece of coral as the seal swam. The net fragment was removed by field personnel. The gray polypropylene fragment measured 30 × 60 cm, had a stretched mesh size of 10.5 cm, and a 2 mm twine diameter. The pup had been entangled through a hole in the web, not in a single mesh.

Incident Three

At 0830 hours on 8 May, a weaned pup was heard vocalizing repeatedly from the reef edge, approximately 100 m offshore from the east side of the island. Closer inspection revealed the male pup to be entangled in an 80 × 30 cm mass of monofilament net and 25 mm diameter polypropylene line. The net apparently had been fouled on the shallow reef for some time, and the pup had become entangled by four strands of the line, two strands each anterior and posterior to the front flippers, girdling the chest. The entire tangle was in water approximately 0.25 m deep, the tide was low, and the seal was held so tightly that had biologists not released the animal, it would almost certainly have drowned during the incipient high tide.

Incident four

At 0830 hours on 9 May, an adult female seal attended by her 26-day-old nursing pup was seen apparently entangled in a mass of net and line at the reef edge, about 75 m off the northeast side of the island. The female appeared to have several coils of line draped over her neck and back. The pup was swimming and vocalizing near the female.

Research personnel prepared equipment for restraining and releasing the female, but upon returning to the site at about 0930 hours, they found the female had freed herself and was ashore nursing her pup. The net which had entangled the female washed ashore later the same day, 200 m west of the entanglement site. The net mass comprised assorted polypropylene lines and monofilament net.

Incident five

At approximately 0900 hours on 23 June, a weaned male pup was found entangled in a net mass on the east side of the island. The net was the same one that entangled a pup on 22 April (incident one). Though the net mass had been previously dragged ashore, high tides and wave surge had moved it about 400 m north, where it was in the wash zone of the beach. The pup was lying atop the pile entangled by a twisted noose of mesh about its neck (Fig. 1). As in incident one, the pup was not in immediate danger of drowning, but was so firmly bound that escape would have been unlikely. Field personnel released the pup and retained the mesh noose. (The net was later moved high up on the beach.)

Discussion

Although the number of hazardous

nets counted on Lisianski was markedly higher in this study than counted by Fiscus et al. (footnote 5) in 1978 (52 versus 18), this amount does not necessarily represent accumulation over 4 years. Some of the nets cataloged in 1982 were found in vegetation well up the beach, and may not have been seen during the 4-day visit in 1978. Criteria by which a net was deemed hazardous may also have been less stringent in 1982 than in 1978. Nonetheless, the large number of fragments accumulating throughout the 6-month field season in 1982 indicates that floating debris is ubiquitous in the waters of the NWHI.

Twenty-six pups survived to weaning at Lisianski in 1982. When field personnel departed the island on 15 September, 25 pups were still alive. The one pup that died was once entangled (incident one), but the death was unrelated to that incident. During a 1-month field camp from 26 October to 22 November, 24 of these pups were seen.

Since all pups were bleach marked, the identity was known of all individuals observed entangled in or investigating nets. The 10 incidents reported here (4 pup entanglements, 6 observations of pups investigating debris) involved 10 different animals, 38.5 percent of the pups of the year. Three of these entanglements could have resulted in death of the monk seal had researchers not intervened. Moreover, the large percentage of pups known to have interacted with nets suggested a general propensity in pups to explore fishing debris. Entanglement of northern fur seals, *Callorhinus ursinus*, is believed to similarly result from investigative behavior by the seals rather than from accidental blundering[6]. This investigative behavior, coupled with the presence of large amounts of such debris, could lead to considerable mortality among recently weaned monk seals. The escape of an apparently entangled adult female suggests that nets and other debris may present less hazard to adults than to pups.

Figure 1.—Hawaiian monk seal pup (59 days postweaning) entangled in a fragment of fishing net.

Acknowledgment

Comments by Linda L. Jones and Joe Scordino improved the manuscript.

Literature Cited

Andre, J. B., and R. Ittner. 1980. Hawaiian monk seal entangled in fishing net. 'Elepaio 41(6):51.

Balazs, G. H. 1979. Synthetic debris observed on a Hawaiian monk seal. 'Elapaio 40(3):43-44.

Beverton, R. J. H. 1982. Report on IUCN Workshop on Marine Mammal/Fishery Interactions, La Jolla, California, 30 March-2 April 1981. Int. Union Conserv. Nat. Nat. Resour., Switzerland, 57 p.

Bonner, W. N., and T. S. McCann. 1982. Neck collars on fur seals, *Arctocephalus gazella*, at South Georgia. Br. Antarct. Surv. Bull. 57:73-77.

Contos, S. M. 1982. Workshop on marine mammal-fisheries interactions. U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., PB82-189507, 64 p.

Fowler, C. W. 1982. Interactions of northern fur seals and commercial fisheries. *In* Trans. 47th North Am. Wildl. Nat. Resour. Conf. 1982, p. 278-292. Wildl. Manag. Inst., Wash., D.C.

Kenyon, K. W. 1980. No man is benign, the endangered monk seal. Oceans 13(3):48-54.

Mate, B. R. 1980. Workshop on marine mammal-fisheries interactions in the northeastern Pacific. U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., PB80-175144, 48 p.

Shaughnessy, P. D. 1980. Entanglement of Cape fur seals with man-made objects. Mar. Pollut. Bull. 11:332-336.

[6]Scordino, J., G. Beekman, H. Kajimura, K. Yoshida, Y. Fujimaki, and M. Tomita. 1984. Investigations on fur seal entanglement in 1983 and comparisons with 1981 and 1982 entanglement data, St. Paul Island, Alaska. Background paper submitted to the 27th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, March 29-April 6, 1984, Moscow, 26 p. + appendices and figures.

Paired Open Beach Seines to Study Estuarine Migrations of Juvenile Salmon

HERBERT W. JAENICKE, ADRIAN G. CELEWYCZ, JACK E. BAILEY, and JOSEPH A. ORSI

ABSTRACT—A paired seine technique was developed to study the timing and direction juvenile Pacific salmon were moving nearshore along straight, long unobstructed beaches in southeastern Alaska. The seines were anchored in place and fished simultaneously in an L-shaped configuration: One seine open in one direction; the other open in the opposite direction. Fishing the paired seines required four people and a small (5.1 m) boat powered by an outboard motor (15 hp minimum).

In 261 paired sets between late March and mid-June of 1981 and 1982, the directional seines were particularly effective in sampling pink salmon, Oncorhynchus gorbuscha *and chum salmon,* O. keta, *fry; coho salmon,* O. kisutch, *smolts; and Dolly Varden,* Salvelinus malma, *smolts and adults. Thirty-eight other species of fish were also captured. Preliminary results showed that pink salmon fry migrating nearshore were most abundant from mid-May to early June and were predominantly migrating north along the west side of upper Chatham Strait.*

Introduction

Marine mortality of pink salmon, *Oncorhynchus gorbuscha*, which is usually very high during their initial coastal migration (Parker, 1968), can be affected by the route and timing of migration to the open sea. Migrations of pink salmon fry toward the sea have been tracked along single inland passages by repeatedly sampling the fish with towed surface trawls or purse seines (Barraclough and Phillips, 1978; Healey, 1980). These fishing methods, however, are not appropriate for southeastern Alaska (Fig. 1) where a myriad of inland passages exists, and the fry can migrate in several directions to the open sea. Thus, we conceived a technique for fishing seines anchored

The authors are with the Auke Bay Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 210155, Auke Bay, AK 99821.

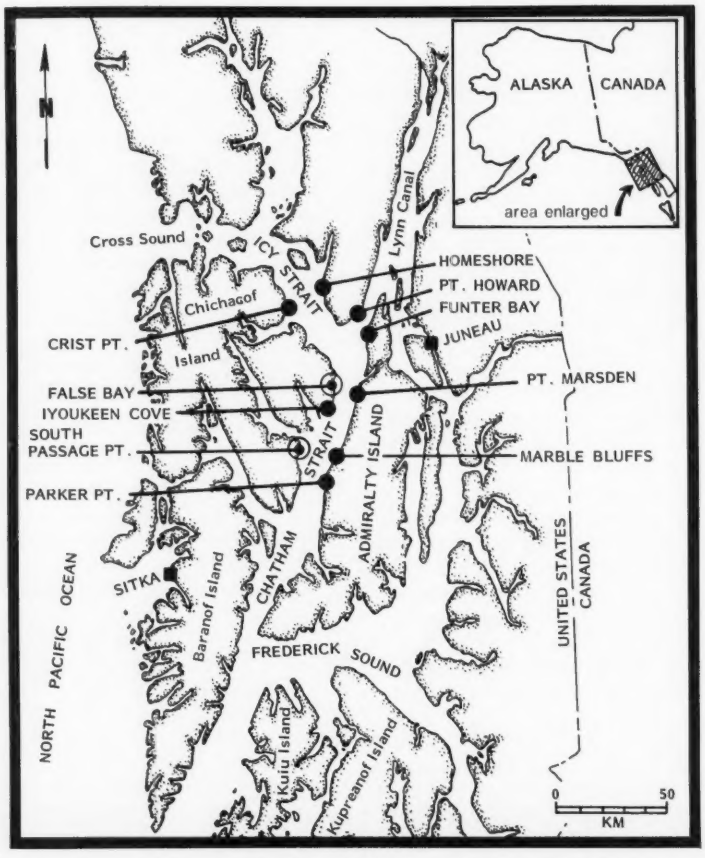


Figure 1.—Location of beach seining sites in the northern part of southeastern Alaska, 1981 and 1982.

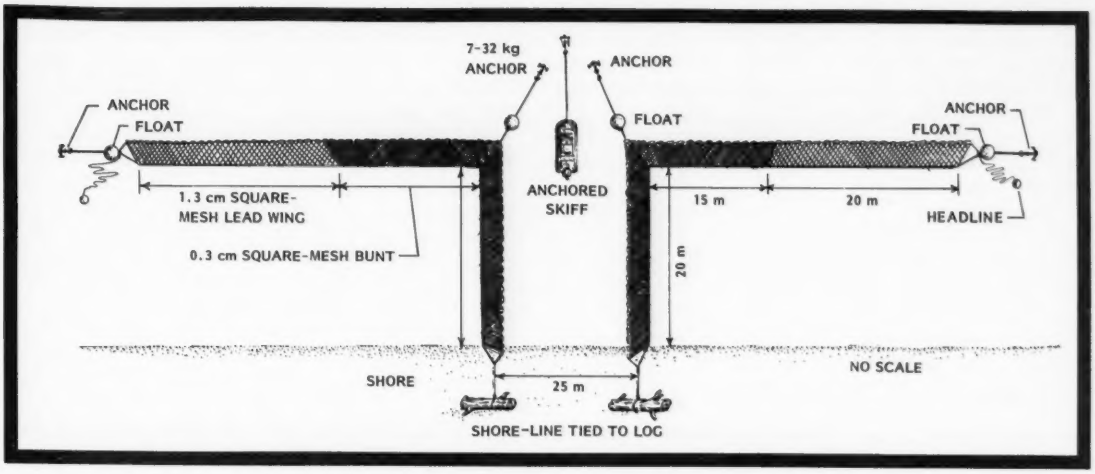


Figure 2.—Specifications and position of the paired beach seines used.

along beaches to determine the direction of movement and timing of nearshore pink salmon fry migrations.

The validity of the method depends on careful selection of beaches. Pink salmon fry spend more time milling about and feeding in protected waters along the shoreline than actively migrating (Healey, 1967). Therefore, our hypothesis is that salmon fry actively migrate along transition beaches—beaches that are long, straight, and smooth, have little protection from current, and offer few opportunities for feeding[1]. Fry caught by directional seining on transition beaches should reveal the predominant direction the fry are migrating.

In this paper, we describe a beach seining technique using directional seines and present preliminary results from 1981 and 1982 that support its validity for determining directional nearshore movements of pink salmon.

Selecting the Beaches

The coast of southeastern Alaska is rocky, and seinable beaches are difficult to find. Ten sites along lower Lynn Canal, Icy Strait, and upper Chatham Strait were chosen (Fig. 1). Most sites were moderately sloped (6-9°), 170-400 m long, unobstructed stretches of sand, gravel, or rubble. Some were sampled often; others only a few times. Results of only two sites in upper Chatham Strait, False Bay and South Passage Point, are described in this paper.

Materials and Methods

Each seine was 55 m long, 3 m deep, and consisted of two sections of nylon web: A lead wing and bunt (Fig. 2). The lead wing was 20 m long and made of white 1.3 cm square mesh (16 kg test). The bunt was 35 m long and made of green 0.3 cm square mesh (20 kg test). The float line was a 1.3 cm diameter blend of polyester polypropylene with a breaking strength of 2,273 kg. The 1.1 cm diameter lead core line weighed 0.3 kg/m and had a breaking strength of 364 kg. The 7.6 cm × 12.0 cm plastic floats had 0.3 kg buoyancy and were spaced 30 cm apart center-to-center on the float line. A 25 m long, 1.1 cm diameter headline was attached to the end of the lead wing, and a variable length shore line was attached to the bunt wing.

Two open seines were simultaneously fished for hour-long sets during the day in 1981 from mid-April through mid-June and in 1982 from late March through mid-June. Both seines were set in the shape of an L, with the opening of one seine facing one direction and the opening of the other seine facing the opposite direction (Fig. 2). After fishing the seines for 1 hour, we closed and brailed them and identified, counted, and released the catches between the seines. The seines were then reset, and the process was repeated up to seven times each day. This seining method requires at least four people and a skiff powered by an outboard motor (15 hp minimum). Activities were minimized near the nets so that migrating fish were not disturbed. Wave lengths over 0.3 m made seining hazardous and injured small fish in the bunt of the seine.

Before the seines were set, each was stacked lead wing first in the bow of a 5.1 m skiff. The end of the bunt was tied to a line attached to a log on the beach. During flood tide, the end of the bunt was tied 1-7 m above the edge of the water, just above where

[1] J. E. Bailey and C. Mattson. Unpubl. data on file at the Auke Bay Laboratory, Northwest and Alaska Fisheries Center, NMFS, NOAA, P.O. Box 210155, Auke Bay, AK 99821.

the tide would reach in 1 hour; thus, fish were prevented from swimming past the net along the shore. During ebb tide, the end of the bunt was tied at the edge of the water. After the seine was tied, one person backed the skiff perpendicular from shore while another person set the seine over the bow. At 20 m from shore, a float, line, and anchor were fastened to a ring on the float line and tossed overboard to become the corner anchor for the seine. The motor operator then backed the skiff in a 90° turn, and the rest of the seine was set parallel to shore. Another float and anchor were then fastened at the end of the net to hold it open (Fig. 2). Ten minutes later, the second seine was tied and set similarly but open in the opposite direction. Each seine in a paired set fished about the same distance offshore at any tidal stage. For each paired set in 1982, the direction the current was moving at the net was noted. When not in use, the skiff was anchored between the two seines.

To close the net, the boat operator ran the skiff to the open end of the seine that had been set first and threw the headline ashore. The person in the bow removed the anchor and float from the open end of the net, and then the shore crew pulled in the headline and lead wing. The corner anchor and float were then removed from the seine, and the skiff was beached. The two crews then pulled both ends of the bunt ashore. Once the catch was put in buckets of water, the seine was restacked in the skiff and set again. The other seine was then closed, the catch removed, and the net reset. Closing, stacking, and resetting a seine required 10-15 minutes.

Table 1.—Catch and size range of the most abundant salmonids caught in paired beach seines in the northern part of southeastern Alaska, April to June 1981, and March to June 1982.

Species	Year	Catch	Fork length range (cm)
Pink salmon	1981	117,018	2.4-8.5
	1982	57,774	2.6-10.5
Chum salmon	1981	15,276	3.1-8.1
	1982	2,401	3.2-6.8
Coho salmon	1981	357	
	1982	1,300	7.5-13.5
Dolly Varden	1981	612	10.5-36.5
	1982	1,511	6.5-46.5

Fish Catches

In 261 paired sets, the open beach seines were successful in catching nearshore salmonids, especially pink and chum salmon, *O. gorbuscha,* fry, and to a lesser extent coho salmon, *O. kisutch*, smolts and Dolly Varden, *Salvelinus malma*, smolts and adults (Table 1). All these fish migrate close to shore for several weeks after leaving freshwater (Scott and Crossman, 1973; Armstrong and Morrow, 1980; Healey, 1980). In 1981 and 1982, we caught 42 species: 8 species of salmonids and 34 other species. In 1982, 91 percent of the catch at all sites consisted of salmonids (mostly pink salmon, Table 2).

The open beach seines were effective in sampling salmon fry up to a mean fork length of 4.5 cm. Pink salmon fry caught in April at False Bay had a mean length of 3.2 cm; chum salmon fry had a mean length of 3.9 cm. In mid-May or early June, when fry were most abundant at this site, mean length of pink salmon fry was 3.6 cm, and mean length of chum salmon fry was 4.5 cm. Few fish larger than 4.5 cm were caught, probably because these fish move offshore, a behavioral change in pink and chum salmon apparently associated with size (LeBrasseur and Parker, 1964; Healey, 1980).

Seasonal Occurrence of Fry

Seasonal migration of the juvenile pink and chum salmon was most ap-

Table 2.—Total abundance of fish and percent composition of catches in paired beach seines at seven sites sampled in southeastern Alaska in March-June 1982. The sites sampled were False Bay, South Passage Point, Homeshore, Pt. Marsden, Iyoukeen Cove, Marble Bluff, and Parker Point.

Scientific name	Common name	Total number	Percentage composition	Scientific name	Common name	Total number	Percentage composition
1. *Oncorhynchus gorbuscha*	Pink salmon	57,774	83.19	21. *Hexagrammos decagrammus*	Kelp greenling	11	0.02
2. *Ammodytes hexapterus*	Pacific sand lance	3,136	4.52	22. *Salmo clarki*	Cutthroat trout	11	0.02
3. *Oncorhynchus keta*	Chum salmon	2,401	3.46	23. *Gasterosteus aculeatus*	Threespine stickleback	9	0.01
4. *Salvelinus malma*	Dolly Varden	1,511	2.18	24. *Hexagrammos stelleri*	Whitespotted greenling	6	0.01
5. *Oncorhynchus kisutch*	Coho salmon	1,300	1.87	25. *Platichthys stellatus*	Starry flounder	5	0.01
6. *Trichodon trichodon*	Pacific sandfish	1,044	1.50	26. *Mallotus villosus*	Capelin	4	0.01
7. *Gadus macrocephalus*	Pacific cod	634	0.91	27. *Oncorhynchus nerka*	Sockeye salmon	3	0.00
8. *Lepidopsetta bilineata*	Rock sole	314	0.45	28. *Pallasina barbata*	Tubenose poacher	3	0.00
9. *Icelus* sp.	Thorny sculpin	227	0.33	29. *Hemilepidotus hemilepidotus*	Red Irish lord	2	0.00
10. *Myoxocephalus* sp.	Great sculpin	213	0.31	30. *Blepsias bilobus*	Crested sculpin	2	0.00
11. *Enophrys bison*	Buffalo sculpin	200	0.29	31. *Eumicrotremus orbis*	Pacific spiny lumpsucker	2	0.00
12. *Hexagrammos* sp.	Greenling	199	0.29	32. *Stichaeus punctatus*	Arctic shanny	2	0.00
13. *Pholis laeta*	Crescent gunnel	144	0.21	33. *Anoplarchus* sp.	High cockscomb	1	0.00
14. *Clupea harengus pallasi*	Pacific herring	122	0.18	34. *Apodichthys flavidus*	Penpoint gunnel	1	0.00
15. *Oligocottus maculosus*	Tidepool sculpin	37	0.05	35. *Aulorhynchus flavidus*	Tube-snout	1	0.00
16. *Liparis callyodon*	Spotted snailfish	34	0.05	36. *Ophiodon elongatus*	Lingcod	1	0.00
17. *Blepsias cirrhosus*	Silverspotted sculpin	29	0.04	37. *Hemilepidotus* sp.	Irish lord	1	0.00
18. *Leptocottus armatus*	Pacific staghorn sculpin	18	0.03	Total		69,438	100.00
19. *Psychrolutes paradoxus*	Tadpole sculpin	18	0.03				
20. *Salmo gairdneri*	Steelhead trout	18	0.03				

parent at False Bay (Fig. 1), the only site frequently seined in both 1981 and 1982. A few recently emerged pink and chum salmon fry were migrating seaward when we started seining in late March 1981 (during exploratory fishing) or early April 1982. In 1981, most of the fry were caught in mid-May; in 1982, most were caught in early June. As many as 27,000 juvenile pink salmon were caught in a single haul. Usually, however, 200-4,500 pink salmon fry and 10-400 chum salmon fry were caught in a paired set during the peak of the nearshore seaward migration. By mid-June in 1981 and 1982, few pink salmon fry or chum salmon fry were being caught.

Table 3.—Directional movement of pink salmon fry at False Bay in 1981 and 1982 and at South Passage Point in 1982.

Site	Pink salmon fry			Number of paired sets		
	Moving north	Moving south	Total	Predominantly northward movement	Predominantly southward movement	Total
False Bay, 1981						
Number	63,675	14,153	77,828	20	6	26
Percent	82	18	100	77	23	100
False Bay, 1982						
Number	39,104	1,873	40,977	47	10	57
Percent	95	5	100	82	18	100
South Passage Point, 1982						
Number	4,485	3,883	8,368	23	17	40
Percent	54	46	100	58	42	100

Analysis for Directionality and Results

We analyzed the data to determine movement of schools of fish rather than movement of individual fish. Our analysis of directionality treats each paired set of seine catches as a separate observation, and all paired sets are weighted equally. Random movement of fish at a site was used as the null hypothesis, and the probability of a paired set indicating a direction of movement from a choice of two possible directions was 0.5. We grouped the paired sets according to the predominant direction of movement of each species at each site and tested for deviation from the predicted value of 0.5. If there were <25 paired sets, we used the binominal test (two-tailed) for equality (Table D in Siegel, 1956). For analyses with >25 paired sets, the binomial distribution approaches the normal distribution; therefore, we used the normal approximation test corrected for continuity (Siegel, 1956):

$$z = \frac{(x \pm 0.5) - NP}{(NPQ)^{1/2}},$$

where z is the standardized random variable, x is the number of paired sets indicating a certain direction of movement at a site, N is the number of paired sets at that site, and P and Q are the probabilities associated with each direction of movement ($P=Q=0.5$). If $x<NP$, $x + 0.5$ was used; if $x>NP$, $x - 0.5$ was used.

Pink salmon fry at the most intensively fished site, False Bay (Fig. 1), migrated northward in 1981 ($P<0.01$) and 1982 ($P<0.001$) (Table 3). A predominant direction of migration was not evident at a nearby site, South Passage Point, which was fished only in 1982 ($P<0.43$) (Table 3).

Discussion

This beach seining technique must be used on long, unobstructed beaches that have a gradient of at least 6°. This gradient allows the net to fish for 1 hour without going dry during ebb tide. The beach must be longer than 170 m so that the seines can be fished next to each other and the crew can maneuver the skiff around the nets.

Pink salmon fry showed the strongest directionality along a beach where the nearshore current was simple, consistent, and predictable with changing tides. Paired sets at sites close to points, shoals, and reefs showed weaker directionality because these obstructions produced nearshore back eddies from the main current that apparently affected fish movement. Paired sets at sites near entrances of large inlets had weak directionality because strong tidal currents helped produce turbulent and complicated current patterns. In 1982, patterns of surface currents at False Bay and South Passage Point were determined by tracking drogues. The nearshore currents at False Bay were usually parallel to the beach (Fig. 3) and were more consistent with the direction of currents in upper Chatham Strait than at South Passage Point, as predicted by the U.S. Department of Commerce (1980). At South Passage Point, however, located only 1 n.mi. (1.8 km) from the entrance of Tenakee Inlet, currents were variable (sometimes circular, sometimes parallel to the beach) because a nearby point deflected the main current (Fig. 3). Most pink salmon fry were migrating north at both sides (Table 3), but the simpler, more consistent current patterns at False Bay apparently resulted in significant directional data there ($P<0.001$) compared with South Passage Point ($P<0.43$).

In 1982, pink salmon fry were not apparently being carried by the prevailing currents. At False Bay, current direction was usually consistent throughout the sets, and fry were predominantly migrating against it ($P<0.05$, Table 4). At South Passage Point, however, the current often changed direction during the sets, and the direction fry were migrating during a paired set was not significantly related ($P<0.86$) to the direction of the current (Table 4). Continuous measurements of nearshore currents are needed to better understand the influence of currents on juvenile salmon migration.

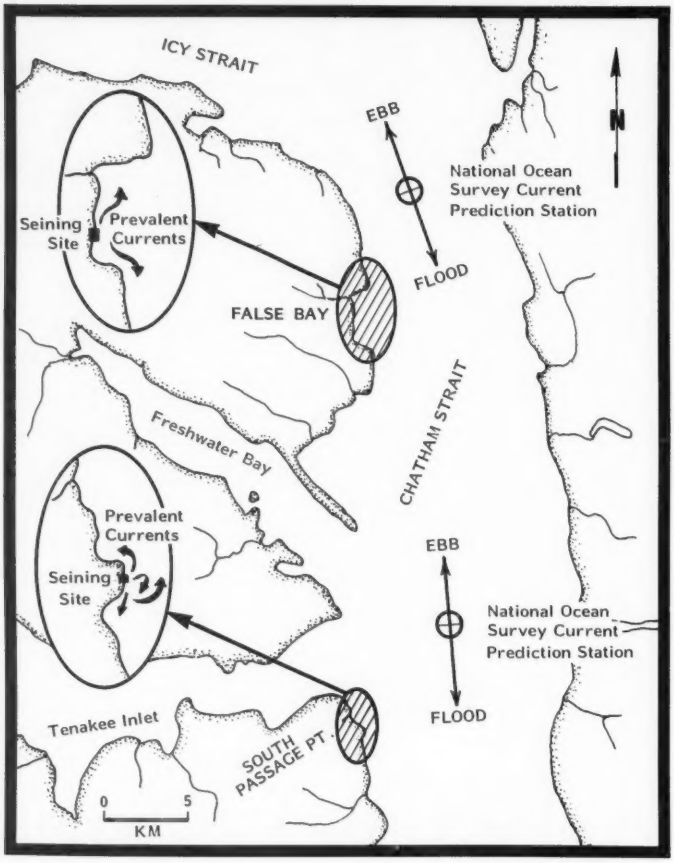


Figure 3.—Direction of nearshore currents at False Bay and South Passage Point in relation to currents in upper Chatham Strait.

migrating rather than milling, as shown by data from False Bay in 1981 (Table 5). On 12 and 14 May 1981 at False Bay, 75 percent of the pink salmon fry were moving north ($P < 0.45$) at Site 1, a 100 m long beach bordered by steep cliffs to the south and a huge boulder to the north (Fig. 4). The cliffs provided protection from wind, waves, and strong currents. Because large numbers of salmon fry were milling about the cliffs, we moved our seining location 260 m to the north to Site 2, a 170 m long unobstructed beach. Catches at Site 2 during the next 2 days indicated 98 percent of the pink salmon fry were moving north ($P < 0.004$).

Each year, more juvenile salmonids are marked and released. Little information is available on the location, migration, and size of these fish during their early marine life. Paired beach seines can be used to study nearshore migrations of juvenile salmonids, and recoveries of marked fish will provide valuable data on the origin, migration routes, nearshore residence, behavior, and growth of individual stocks. Directional seining can also be used to study the nearshore migrations of other fishes in estuaries, lakes, and reservoirs.

Furthermore, the study sites for using paired beach seines must be in areas where salmonids are actively

Acknowledgments

We thank Chris Bartholomew, Robert Budke, Ronald Heintz, Donald Mortensen, and other personnel at the Auke Bay Laboratory for their invaluable assistance, and Noranda Exploration, Inc., for the use of their housing at Hawk Inlet. We also appreciate the help given us by the crews of the NOAA fishery

Table 4.—Number of paired sets with pink salmon fry moving predominantly with or against the nearshore currents at False Bay and South Passage Point in 1982.

Site	Number of paired sets with predominant direction of pink salmon fry movement	
	With current	Against current
False Bay	10	22
South Passage Point	18	16

Table 5.—Directional movement of pink salmon fry at two sites in False Bay 1981.

Site	Pink salmon fry			Number of paired sets		
	Moving north	Moving south	Total	Predominantly northward movement	Predominantly southward movement	Total
Site 1						
Number	38,235	12,738	50,973	5	2	7
Percent	5	25	100	71	29	100
Site 2						
Number	24,418	456	24,874	9	0	9
Percent	98	2	100	100	0	100

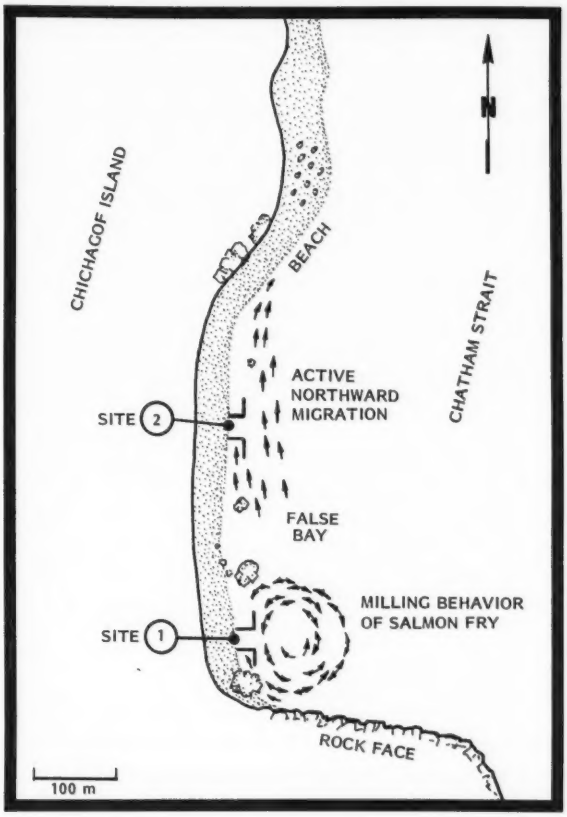


Figure 4.—Areas where juvenile salmon were milling or actively migrating northward at False Bay, southeastern Alaska.

research vessels *Murre II* and *John N. Cobb*, the U.S. Fish and Wildlife vessel *Curlew*, the Alaska Department of Fish and Game vessel *Kittiwake*, and the University of Alaska at Juneau vessel *Maybeso*.

Literature Cited

Armstrong, R. H., and J. E. Morrow. 1980. The Dolly Varden charr, *Salvelinus malma*. *In* E. K. Balon (editor), Charrs, salmonid fishes of the genus *Salvelinus*, p. 99-140. Dr. W. Junk, The Hague, Netherlands.

Barraclough, W. E., and A. C. Phillips. 1978. Distribution of juvenile salmon in the southern Strait of Georgia during the period April to July 1966-1969. Fish. Mar. Serv. Tech. Rep. 826, 47 p.

Healey, M. C. 1967. Orientation of pink salmon (*Oncorhynchus gorbuscha*) during early marine migration from Bella Coola River system. J. Fish. Res. Board. Can. 24:2321-2338.

Healey, M. C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. *In* W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific, p. 203-229. Oreg. St. Univ. Press, Corvallis.

LeBrasseur, R. J., and R. R. Parker. 1964. Growth rate of central British Columbia pink salmon (*Oncorhynchus gorbuscha*). J. Fish. Res. Board Can. 21:1101-1128.

Parker, R. R. 1968. Marine mortality schedules of pink salmon of the Bella Coola area, British Columbia. J. Fish. Res. Board Can. 25:757-794.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board. Can. Bull. 184, 966 p.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. Mc-Graw-Hill, N.Y., 312 p.

U.S. Department of Commerce. 1980. Tidal current tables, 1981, Pacific coast of North America and Asia. U.S. Gov. Print. Off., Wash., D.C., 260 p.

Nonselectivity of Gillnet Fishery on Jaw-tagged Adult Steelhead, *Salmo gairdneri*

EMIL SLATICK and LARRY BASHAM

Introduction

Since 1968, the National Marine Fisheries Service (NMFS) has been conducting experiments to determine whether transporting juvenile Pacific salmon, *Oncorhynchus* spp., and steelhead, *Salmo gairdneri*, around a series of dams on the Snake and Columbia Rivers is a feasible method of increasing smolt survival during seaward migrations (Ebel et al., 1973; Slatick et al., 1975). Evaluation of these experiments depended on a facility capable of separating returning adults tagged with internal magnetic coded wire tags (CWT) from nontagged adults. Such a trap was installed in the fish ladder at Little Goose Dam on the Snake River (Ebel, 1974). Jaw tags placed on adults with CWT intercepted at this trap provided a means of subsequent visual identification of these fish when they were recovered at upstream hatcheries or other locations (Slatick, 1976). In August 1978, a similar facility began operating in the Washington shore fishway of Bonneville Dam (Fig. 1) on the Columbia River.

ABSTRACT—In 1978, three small lots of actively migrating adult steelhead, Salmo gairdneri, *were marked with an operculum punch (a small hole punched in the operculum) or an operculum punch and a metal jaw tag. The objective of the study being done at Bonneville Dam on the Columbia River was to determine whether jaw-tagged steelhead were more susceptible to being captured in gill nets than non-jaw-tagged steelhead. An analysis of mark recoveries obtained from the gillnet fishery upstream from Bonneville Dam showed no statistical difference in recoveries between jaw-tagged and non-jaw-tagged steelhead.*

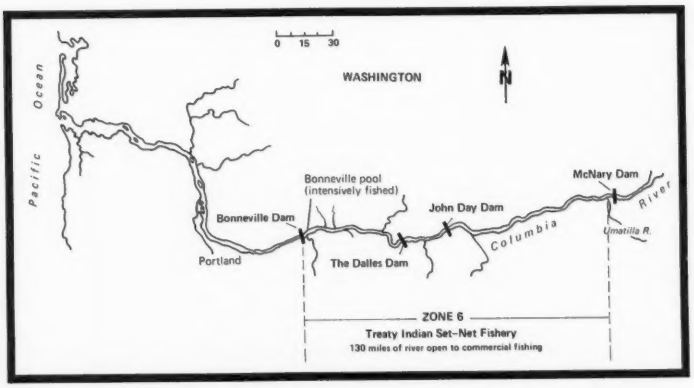


Figure 1.—Map of study area showing the Columbia River and the treaty Indian gillnet zone above Bonneville Dam.

An intensive gillnet fishery exists during the fall in the reservoir above Bonneville Dam. Adult salmonids passing upstream over the dam during the fishing season are susceptible to the fishery. Since our normal marking procedure required placing a jaw tag on specific wire-tagged fish intercepted at the dam, a question arose as to whether jaw-tagged fish were more susceptible to being caught in gillnets than non-jaw-tagged fish. This report describes an experiment designed to answer the question.

Methods and Procedures

Steelhead used in the experiment from 25 to 31 August 1978 were trapped in the Fisheries Engineering Research Laboratory located at Bonneville Dam on the Columbia River (Collins and Elling, 1960). Three groups of fish were released: A test and a control group consisting of randomly selected untagged adult steelhead (100/group), and a smaller test group of 19 steelhead which were previously marked with CWT as juveniles in the transportation study.

Each fish was marked with a ¼-inch (6.35 mm) diameter hole punched in its right operculum. These small holes were placed in one of three positions: Upper, center, or lower area of the operculum (Control, Test 1, and Test 2 Groups, respectively) (Fig. 2). Fish from Test Groups 1 and 2 were also marked with jaw tags made of monel or tempered aluminum bands (National Band

Emil Slatick is with the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. Larry Basham is with the Water Budget Center, 2705 East Burnside, Suite 213, Portland, OR 97214.

Company, size 12 through 24)[1] which were shaped and tightened around their lower mandible (Fig. 3). Untagged fish destined for the Control Group and Test Group 1 were alternately marked with an operculum punch only (control) or an operculum punch and a jaw tag (test) throughout the marking period so that bias due to size and migratory behavior would be reduced to a minimum. After being tagged, fish were released into the fish ladder to continue their upstream migration. Recoveries of these fish from the gillnet fishery were obtained from the sampling program conducted by state and Federal agencies during the duration of the fishery, from 25 August to 3 October 1978.

Test Groups 1 and 2 were combined to set up a 2×2 contingency table for determining differences in recovery rate between test and control releases. Formulas developed by Kappenman (1983) provided the means to determine whether there was independence ($G_1 > G_2$) between the two tagging methods (no gillnet selectivity) or dependence ($G_2 > G_1$) and therefore selectivity of jaw-tagged fish in the gillnet fishery. The G formulas are:

$$G_1 = \sum_{ij} x_{ij} \log e_{1_{ij}},$$

$$G_2 = \sum_{ij} x_{ij} \log e_{2_{ij}},$$

where

$$e_{1_{ij}} = (x_i - 1)\frac{(x_1\, j-1)}{n-1},$$

$$e_{2ij} = x_{ij} - 1,$$

x_{ij} = the observations in the cells of the 2×2 contingency table, and

n = the total number of observations in the contingency table.

[1] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

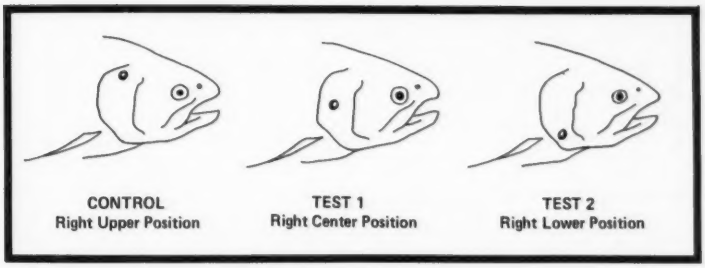


Figure 2.—Position of opercular punches used on the test fish.

Figure 3.—Position of a jaw tag placed on a steelhead.

Results and Discussion

A total of 6,172 steelhead were sampled from the gillnet fishery, and 27 marked fish were recovered: 9 (9 percent) from the Control Group, 16 (16 percent from Test Group 1, and 2 (10.5 percent) from Test Group 2 (Table 1). The recovery rate for the combined Test Groups was 15 percent versus 9 percent for the Control Group. Although the percentage return of test fish was higher, the difference was not sufficient to indicate gillnet selectivity on jaw-tagged fish ($G_1 = 944.424 > G_2 = 944.318$). It should be pointed out that the differences in recovery rates may be less than indicated in Table 1. Even though fishery agency personnel were checking the fishery carefully, there was potential for some bias toward

Table 1.—Comparative recovery of marked steelhead from the gillnet fishery above Bonneville Dam.

Mark	Fish marked	Fish recovered	
		Number	Percent
Upper operculum punch (Control)	100	9	9.0
Jaw tag and center operculum punch (Test 1)	100	16	16.0
Jaw tag and lower operculum punch (Test 2)	19	2	10.5
Tests 1 and 2 combined	119	18	15.0
Totals	219	27	

recovery of test fish because operculum punches were harder to see than jaw tags. Consequently, a few control fish might have been overlooked in the sampling process. Since the test results showed the same probability of recovery for jaw-tagged as for non-jaw-tagged fish in the gillnet fishery, we concluded that jaw tags can be used as a tagging method for additional upstream evaluation without concern about potential bias from gillnet selectivity.

Acknowledgments

The authors wish to thank personnel from the Washington Department of Fisheries, Washington Department of Game, Oregon Department of Fish and Wildlife, Yakima Indian Nation, and U.S. Fish and Wildlife Service for assisting in recovering tag data from the gillnet fisheries. We also thank Frank Ossiander of the National Marine Fisheries Service for statistical treatment of the data.

Literature Cited

Collins, G. B., and C. H. Elling. 1960. Fishway research at the Fisheries-Engineering Research Laboratory. U.S. Fish Wildl. Serv. Circ. 98, 17 p.

Ebel, W. J. 1974. Marking fishes and invertebrates. III. Coded wire tags useful in automatic recovery of chinook salmon and steelhead trout. Mar. Fish. Rev. 36(7):10-13.

_____, D. L. Park, and R. C. Johnson. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull. 71:549-563.

Kappenman, R. F. 1983. On the inferential use of predictive sample reuse. Comm. Stat. Theor. Meth. 12(3):363-380.

Slatick, E. 1976. Comparative retention of dart and jaw tags on chinook salmon and steelhead trout during their spawning migration. Mar. Fish. Rev. 38(7):24-26.

_____, D. L. Park, and W. J. Ebel. 1975. Further studies regarding effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull. 73:925-931.

Proximate Composition of Certain Red Sea Fishes

RIFAAT G. M. HANNA

Introduction

Knowledge of the proximate composition of fishes can be used to estimate the food value of fishes and to plan the most appropriate industrial and commercial processing. Early, though long outdated, data on the chemical composition of fishes were given by Priestly (1790), Biot (1807), Morin (1822), Weigelt (1891), and many others.

The first Egyptian fish samples from the Mediterranean Sea were analyzed by Milone (1896) and El-Saby (1934). The only work on the Red Sea fishes was done by Latif and Fouda (1976). They analyzed fish samples from the Al-Ghardaga area, though interpretation of their results was limited and they did not indicate age or sex of the specimens.

Many Red Sea fishes are important commercially so classification by fat and protein content (Stansby, 1962) may be of value. This study covers 19 species (Table 1) belonging to 10 families which were collected from the Red Sea between Ras Shukier, in the north, to Qoseir, in the south, during two seasons, winter and summer, in 1980.

Table 1.—Scientific and common names of the fishes examined.

Family	Serial no.	Scientific name	Local common name
I. Serranidae	1	*Epinephelus fasciatus*	Koshar Abu-loulow
	2	*Epinephelus areolatus*	Koshar Ads
	3	*Cephalopholis miniatus*	Koshar Nawara
	4	*Variola louti*	Koshar sherif
II. Signidae	5	*Siganus oramin*	Segan
III. Mullidae	6	*Upeneus tragula*	Enpir Assfar
IV. Lethrinidae	7	*Lethrinus genivittatus*	Driny
	8	*L. mahsena*	Mehsenaa
	9	*L. harak*	Pongez
V. Balistidae	10	*Odonus niger*	Shoarom Eswad
	11	*Balistoides viridescens*	Shoarom
VI. Labridae	12	*Thalassoma lunare*	Mallass
	13	*Cheilinus trilobatus*	Mallass Abu-Sabiba
	14	*Coris angulata*	Mallass Gorap
VII. Acanthuridae	15	*Ctenochaetus strigosus*	Kahma
VIII. Lutjanidae	16	*Lutjanus fulviflamma*	Hebria Om-nokta
IX. Hemirhamphidae	17	*Hemirhamphus marginatus*	Gambaror
X. Sparidae	18	*Acanthopagrus bifasciatus*	Rabaag
	19	*Chrysophrys haffara*	Haffara

ABSTRACT—Moisture, protein, fat, and ash content of muscle and gonads were determined for 19 species of 10 fish families, inhabiting coral reef areas of the coastal Egyptian Red Sea waters, which were collected in winter and summer 1980. Values of these parameters appear to vary widely depending on a number of factors including age, sex, season, and species. The fish samples were classified into five fat-protein content categories: Low oil-high protein, medium oil-high protein, high oil-low protein, low oil-very high protein, and low oil-low protein.

Methods

Fishes were collected, tightly sealed in plastic bags, and deep frozen (−20°C) until examination. Date and location of collection were recorded for each specimen. Subsequently, the fishes were identified, and the length, weight, sex, and age were determined. The skin was removed from the flesh. The entire muscle portion of each fish was cut from the vertebral column, and bones were removed. The entire muscle portion, and also the gonad (ovary or testis), of each fish sample was homogenized in a Waring blender[1]. The homogenated sample was used for all the analyses. At least four fish of a species were sampled to represent each parameter (length, weight, age, and sex). The mean values of the proximate composition of the four fish samples were calculated to represent each

Rifaat G. M. Hanna is with the Institute of Oceanography and Fisheries, 101 Kaser El-Ainy Street, Cairo, Egypt.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

parameter. Age was determined by otolith examination.

Moisture Content

Moisture (water) content was determined by the method in FAO (1981). Labelled moisture dishes, with a layer of acid-washed sand in the bottom, were left to dry overnight in an oven at 105°C. Then they were removed, dried, and cooled in a desiccator for 30 minutes. The dishes were weighed accurately using an analytical balance ($W1$). Triplicate representative samples of flesh and gonads (5-10 g) were then placed into the dishes and reweighed ($W2$). Then they were left overnight in an oven at 105°C, and reweighed ($W3$) after 30 minutes of cooling in a desiccator. The percentage of moisture was calculated as follows:

$$\text{Percent moisture} = \frac{(W2 - W3) \times 100}{(W2 - W1)}.$$

Protein Content

Total protein was determined using the Walker and Youngson (1975) method, which is based on the Snow (1950) and Dyer et al. (1950) procedures. Duplicate portions of the homogenate were dissolved by heating in 0.2N NaOH containing 0.5 percent w/v KI at 100°C for 10 minutes; Biuret reagent was then added. After 10 minutes at 37°C the optical density was measured at 545 nm against a reagent blank using a Perkin-Elmer spectrophotometer model 550S. Standard solutions of bovine serum albumin were similarly treated.

Snow (1950) proved that this Biuret method gives results within 2 percent of the micro-Kjeldahl values. Walker and Youngson (1975) compared the results of Biuret method with two other methods: First with the estimation from the nitrogen values (i.e., the nitrogen values multiplied by the conversion factor of 6.25); second, with that calculated from the addition of the weights of the individual amino acids. They found that the total protein content expressed as a function of nitrogen values was about 4 percent higher than the values of Biuret method, which in turn were about 4 percent lower than the values of the total weights of the amino acids.

Fat Content

Fat was extracted into ethyl ether from the dried samples in a standard soxhlet apparatus for 36 hours; the ethyl ether was evaporated to dryness in a rotary evaporator, and the fat was determined gravimetrically (Latif and Fouda, 1976).

Mineral (Ash) Content

Duplicate samples (5-10 g) were ashed in a muffle furnace for 6 hours at 550° C. The weight of the residual ash, expressed as a percentage of the wet sample weight, was taken as the total inorganic residue (mineral content).

Results and Discussion

The reliability of the methods for assessing moisture, protein, fat, and ash were assessed by taking seven replicate samples from the same specimen: *Odonus niger*, 3 years old, total length 37 cm, weight 430 g. The standard deviations for the estimates of water, protein, fat, and ash were calculated. The variability (S.D.) in the estimates of protein, fat, water, and ash content of replicate samples from the same specimen, were ±0.851, ±0.213, ±1.856, and ±0.298 percent, respectively.

Age Variation

The moisture, protein, fat, and ash content results sometimes showed unaccountable fluctuations even between specimens of the same species, age, and sex and from the same catch. Thus, it is useful for the interpretation of the results to calculate them as average values for each species and then for each family.

The mean and standard deviation values and ranges of moisture, protein, fat, and ash content in the muscles of all age groups of fishes of different species and families are given in Table 2 as percent of wet weight. The mean values of the proximate composition in Table 2 of a given species express the average values of four fish of each male and female of the four age groups studied (1st-, 2nd-, 3rd-, and 4th-year age groups). Average moisture values for all year-groups ranged from 81.12 percent for *Odonus niger* to 73.62 percent for *Chrysophrys haffara*, and standard deviation ranged from ±2.33 for *Upeneus tragula* to ±0.41 for *Hemirhamphus marginatus*.

Average protein values ranged from 23.13 percent for *Chrysophrys haffara* to 16.61 percent for *Odonus niger*, and the standard deviation ranged from ±1.84 for *Upeneus tragula* to ±0.12 for *Cheilinus trilobatus*. Average fat content ranged from 1.74 percent for *Thalassoma lunare* to 0.75 percent for *Acanthopagrus bifasciatus*, and standard deviation values ranged from ±0.79 for *Variola louti* to ±0.07 for *Epinephelus areolatus*. Average ash content ranged between 2.11 percent for *Chrysophrys haffara* to 0.91 percent for *Lethrinus harak*, and the standard deviation ranged from ±0.71 for *Epinephelus fasciatus* to ±0.02 for *Acanthopagrus lifasciatus*.

Figure 1 shows the relationship between age and the moisture, protein, fat, and ash content in the muscle of *Variola louti*. Muscle moisture content varied inversely with the amount of fat (i.e., when moisture was highest, fat content was lowest and vice versa). Generally, there was an increase in fat and less water content in flesh with increasing size (i.e., increasing age). The fluctuations of water, fat, protein, and ash values with age of the fishes may be due in part to migration and spawning (Zaitsev et al., 1969; Waters, 1982).

My results agree with those of Vinogradov (1953) who recorded a minimum moisture content of 75 percent for the family Sparidae. Some of my data also agrees with those of Latif and Fouda (1976) who found a moisture content for *Lethrinus mohsena* of 78.7 percent, compared with my average of 78.86 percent. Figure 1 also shows that the smaller the amount of ash, the less the

Table 2.—Moisture, protein, fat, and ash content (mean, standard deviation, and range) in the muscle of all age groups of fishes studied (as percent of wet weight).

Family and species	Moisture			Protein			Fat			Ash		
	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
I. Serranidae (all species)	77.64	0.86	74.33-79.70	19.83	1.20	17.72-21.72	1.15	0.14	0.43-2.30	1.58	0.34	1.01-2.28
1. *Epinephelus fasciatus*	77.77	1.42	76.36-79.20	19.91	1.12	19.01-20.60	1.23	0.61	0.84-1.92	1.47	0.71	1.01-2.28
2. *Epinephelus areolatus*	77.27	1.21	76.12-78.53	20.50	1.10	19.35-21.55	1.07	0.07	1.00-1.14	1.17	0.03	1.14-1.20
3. *Cephalopholis miniatus*	78.76	0.96	77.78-79.70	18.28	0.65	17.72-19.00	1.00	0.16	0.82-1.11	1.96	0.17	1.77-2.10
4. *Variola louti*	76.75	1.68	74.33-78.00	20.31	0.95	19.60-21.72	1.31	0.79	0.43-2.30	1.71	0.06	1.66-1.79
II. Siganidae	77.45	0.96	76.39-78.28	20.12	1.12	19.05-21.38	0.98	0.13	0.84-1.10	1.39	0.31	1.04-1.6
5. *Siganus oramin*	77.45	0.96	76.39-78.28	20.12	1.12	19.05-21.38	0.98	0.13	0.84-1.10	1.39	0.31	1.04-1.6
III. Mullidae	77.48	2.33	74.79-78.92	20.23	1.84	19.14-22.36	1.02	0.12	0.93-1.10	1.27	0.32	1.08-1.64
6. *Upeneus tragula*	77.48	2.33	74.79-78.92	20.23	1.84	19.14-22.36	1.02	0.12	0.93-1.10	1.27	0.32	1.08-1.64
IV. Lethrinidae (all species)	78.06	1.84	75.22-80.47	20.02	2.18	17.62-23.63	1.12	0.18	0.81-1.52	1.06	0.15	0.74-1.37
7. *Lethrinus genivittatus*	75.93	0.96	75.22-77.02	22.53	0.96	21.93-23.63	1.22	0.30	0.93-1.52	1.20	0.17	1.03-1.37
8. *Lethrinus mahsena*	79.06	0.69	78.53-79.84	18.66	0.91	17.62-19.42	1.22	0.19	1.04-1.41	1.08	0.07	1.01-1.14
9. *Lethrinus harak*	79.18	1.19	78.12-80.47	18.87	0.86	18.03-19.75	0.91	0.10	0.81-1.00	0.91	0.24	0.74-1.19
V. Balistidae (all species)	79.73	1.97	77.69-83.01	17.63	1.44	15.13-19.02	1.28	0.49	0.74-2.09	1.55	0.28	1.10-2.29
10. *Odonus niger*	81.12	1.91	79.20-83.01	16.61	1.49	15.13-18.10	0.93	0.21	0.74-1.15	1.35	0.25	1.10-1.60
11. *Balistoides viridescens*	78.34	0.66	77.69-79.21	18.20	0.64	17.53-19.02	1.63	0.36	1.25-2.09	1.75	0.59	1.21-2.29
VI. Labridae (all species)	78.26	1.24	76.69-80.20	18.92	0.99	18.23-20.15	1.23	0.24	0.86-1.82	1.57	0.51	0.82-2.26
12. *Thalassoma lunare*	77.50	0.71	76.99-78.00	18.65	0.59	18.23-19.07	1.74	0.11	1.66-1.82	2.09	0.25	1.9 -2.26
13. *Cheilinus trilobatus*	79.69	0.74	79.15-80.20	18.08	0.12	18.00-18.16	1.19	0.47	0.86-1.52	1.08	0.18	0.95-1.21
14. *Coris angulata*	77.58	0.77	76.69-78.07	20.02	0.15	19.85-20.15	1.23	0.24	1.03-1.50	1.54	0.64	0.82-2.03
VII. Acanthuridae	76.45		76.45	20.04		20.04	1.57		1.57	1.88		1.88
15. *Ctenochaetus strigosus*	76.45		76.45	20.04		20.04	1.57		1.57	1.88		1.88
VIII. Lutjanidae	77.37		77.37	20.00		20.00	1.22		1.22	1.58		1.58
16. *Lutjanus fulviflamma*	77.37		77.37	20.00		20.00	1.22		1.22	1.58		1.58
IX. Hemirhamphidae	75.79	0.41	75.50-76.04	21.81	0.75	21.3 -22.32	1.27	0.13	1.17-1.36	1.11	0.19	0.97-1.24
17. *Hemirhamphus marginatus*	75.79	0.41	75.50-76.07	21.81	0.72	21.3 -22.23	1.27	0.13	1.17-1.36	1.11	0.19	0.97-1.24
X. Sparidae (all species)	76.12	3.54	73.21-79.03	21.26	2.65	19.11-23.54	0.95	0.28	0.66-1.28	1.68	0.61	1.23-2.23
18. *Acanthopagrus bifasciatus*	78.62	0.59	78.20-79.03	19.38	0.37	19.11-19.64	0.75	0.13	0.66-0.84	1.25	0.08	1.23-1.26
19. *Chrysophrys haffara*	73.62	0.59	73.21-74.03	23.13	0.58	22.72-23.54	1.15	0.18	1.02-1.28	2.11	0.18	1.98-2.23

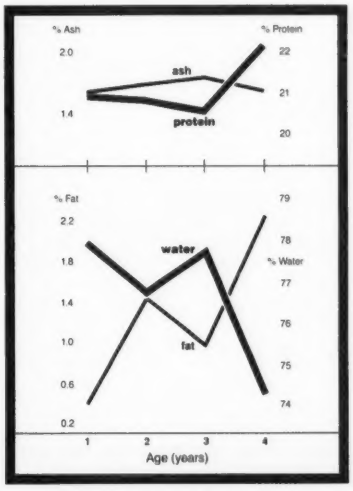


Figure 1.—Age and proximate composition of *Variola louti* muscle.

Table 3.—Sex differences in the proximate composition of fish muscle and gonads (as percent of wet weight).

Species Habitat Capture date	Sex	Organ	Mean fish length (cm)[1]	Age (years)	Mean proximate composition (%)[2]			
					Water	Protein	Fat	Ash
Siganus oramin	M	Muscle	15.5	1	73.88	23.64	1.18	1.40
Qoseir	F	Muscle	15.5	1	78.80	19.68	0.66	0.92
25 Aug. 1980	M	Muscle	17	2	75.4	22.80	1.02	
	F	Muscle	19	2	77.37	19.95	1.00	1.66
Lethrinus genivittatus	M	Muscle	16.8	1	76.31	21.82	0.92	0.96
Safaga	M	Testes	16.8	1	73.36	22.84	0.98	2.75
30 May 1980	M	Muscle	18	1	75.30	22.04	1.12	1.48
	M	Testes	18	1	73.37	23.56	1.05	2.01
	F	Muscle	17	1	77.40	20.63	0.94	1.03
	F	Ovaries	17	1	72.45	23.75	1.10	2.70
Lethrinus harak	M	Muscle	13	1	75.95	21.85	0.92	1.26
Safaga	F	Muscle	13	1	78.20	19.60	0.88	1.28
30 May 1980	M	Muscle	21	2	79.15	18.52	0.93	1.30
	F	Muscle	21.5	2	80.06	18.01	0.91	1.04
	M	Muscle	27.0	3	79.40	19.00	0.82	0.82
	F	Muscle	29.0	3	81.50	17.05	0.80	0.65
Balistoides viridescens	M	Muscle	39.6	3	78.80	18.80	1.66	1.48
Safaga	M	Testes	39.6	3	72.48	23.77	1.21	2.60
4 Feb. 1980	F	Muscle	40.0	3	78.85	17.53	1.46	2.20
	F	Ovaries	40.0	3	70.60	25.07	1.63	2.69

[1]Average length of four fish samples.
[2]Average proximate composition of four fish samples.

moisture content (i.e., the amount of mineral substances in the flesh of fishes was directly correlated with the amount of moisture).

Variation by Sex

Table 3 presents the proximate composition of muscle and gonads of

fishes of each sex collected from the same habitat at the same time. The flesh of males contains less moisture and more protein and fat than that of females. Also, the ovaries contained more protein and fat than the testes, though the ovaries had less water than the testes and even less than the flesh itself. Zaitsev et al. (1969), Hinard (1931), Giménez (1934), and many others have given similar data. The results of this study of ash content of the flesh and genital organs of male and female fishes were not consistent; the data show no regularity. Generally, the mineral content in the different tissues of the fishes showed marked fluctuations.

Table 4.—Seasonal variations in the proximate composition of flesh of some Red Sea fishes (as percent of wet weight) harvested in 1980.

Species	Habitat	Month	Mean fish length (cm)[1]	Mean fish weight (g)[2]	Age (years)	Mean proximate composition (%)[3]			
						Water	Protein	Fat	Ash
Upeneus tragula	Qoseir	Jan.	17.8	2	61	78.83	19.21	0.99	1.19
	Safage	May	19.0	2	66	74.79	22.36	1.16	1.64
Lethrinus genivittatus	Hurgada	Feb.	13.5	1	16	75.61	22.21	1.16	0.98
	Ras-Shuker	Feb.	15	1	44	73.12	23.41	1.87	1.60
	Safaga	May	17	1	60	77.40	20.63	0.94	1.03
	Safaga	May	16.8	1	56	76.31	21.82	0.92	0.96
	Ras-Shuker	Feb.	17	2	72	72.60	23.63	2.11	1.72
	Safaga	May	18.5	2	75	77.83	20.22	0.93	1.02
Lethrinus harak	Hurgada	Feb.	17	1	66	78.77	19.05	0.95	1.26
	Safaga	May	16	1	53	79.57	18.51	0.88	0.97
	Ras-El-Zeit	Feb.	23	2	189	77.59	19.83	1.20	1.38
	Safaga	May	21.5	2	188	80.06	18.01	0.91	1.04
	Safaga	May	29	3	300	81.50	17.05	0.78	0.65
	Safaga	Feb.	27	3	242	79.40	19.00	0.84	0.82
Siganus oramin	Qoseir	Jan.	15.5	1	60	78.80	19.68	0.66	0.92
	Qoseir	Aug.	15.5	1	68	73.88	23.64	1.18	1.40
	Qoseir	Jan.	17	2	75	77.37	19.95	1.00	1.66
	Qoseir	Aug.	19	2	80	75.40	22.80	1.02	1.40

[1]Average length of four fish samples.
[2]Average weight of the four fish samples.
[3]Average proximate composition of the four fish samples.

Seasonal Variation

The proximate composition of the flesh of some fishes collected during winter and summer shows a seasonal change (Table 4). Protein and fat content peaked in early summer after dropping to a low in winter for *Siganus oramin* and *Upeneus tragula*; water content showed an opposite trend. *Lethrinus genivittatus* and *L. harak*, on the other hand, showed minimum fat and protein content in summer and maximum levels in winter.

Waters (1982) and Zaitsev (1969) reported that seasonal variation in chemical composition is due to an alternate accumulation and expenditure of fat and protein. Fish have a minimum fat content after spawning, and a maximum at the end of the feeding season. When fish were in poor condition during migration and spawning, the fat and protein content of their flesh went down and the water content went up; during the feeding period after spawning, the flesh became fatter and its water content decreased. Therefore, *Upeneus tragula* and *Siganus oramin* had maximum fat and protein content by the end of May.

Al-Kholy (1972) reported that *Upeneus tragula* migrated to the Safaga area for intensive feeding in mid-May for 2 weeks; then after another 2 weeks started another migration for spawning. Al-Kholy (1972) also reported that most species of Lethrinidae started their spawning migrations between the end of April and mid-June. So *Lethrinus genivittatus* and *L. harak* had minimum fat and protein content in May due to reproductive activity, including gonad development, migration, and spawning (i.e., expenditure of fat and protein).

Table 5.—Fish species categorized[1] by fat and protein content.

Species	Fat content (range, %)	Protein content (range, %)	Category
1. *Epinephelus fasciatus*	0.84-1.92	19.01-22.18	A-D
2. *Epinephelus areolatus*	1.03-1.10	19.35-21.65	A-D
3. *Cephalopholis miniatus*	0.82-1.11	17.72-19.00	A
4. *Variola louti*	0.43-2.30	19.50-21.72	A-D
5. *Siganus oramin*	0.66-1.18	16.00-23.64	A-D
6. *Upeneus tragula*	0.93-1.16	19.14-22.36	A-D
7. *Lethrinus genivittatus*	0.92-2.11	19.01-23.63	A-D
8. *Lethrinus mahsena*	0.95-1.41	17.62-20.21	A-D
9. *Lethrinus harak*	0.79-1.20	17.05-21.85	A-D
10. *Odonus niger*	0.74-1.15	15.13-18.10	A
11. *Balistoides viridescens*	1.25-2.09	17.53-19.04	A
12. *Thalassoma lunare*	1.66-1.80	18.23-19.07	A
13. *Cheilinus trilobatus*	0.84-1.58	18.02-18.10	A
14. *Coris angulata*	1.03-1.50	19.40-20.98	A-D
15. *Ctenochaetus strigosus*	1.54-1.60	20.00-20.08	A
16. *Lutjanus fulviflamma*	1.16-1.28	22.76-22.83	D
17. *Hemirhamphus marginatus*	1.17-1.36	21.30-22.32	D
18. *Acanthopagrus bifasciatus*	0.66-0.84	19.11-19.64	A
19. *Chrysophrys haffara*	1.02-1.28	22.72-23.54	D

[1]After Stansby (1962).

Fish Categories

The fishes studied were classified by fat and protein content into the five categories of Stansby (1962) (Table 5). Seven species lie in

Category A, the most common type (protein content between 15 and 20 percent and fat content <5 percent). All species in Category A have a fat content <2 percent. Only three species, *Lutjanus* sp., *Hemirhamphus marginatus*, and *Chrysophrys haffara* fall in Category D, and they exhibit a very high protein content (over 20 percent).

Most species, e.g., *Epinephelus areolatus*, *Variola louti*, and *Siganus oramin*, belong primarily to Category A, while the second leading category is D. So, according to Stansby's classification, these Red Sea fishes fall under the Categories A and D, characterized by low fat content (<2.3 percent) and very high protein content (15-23.6 percent). Latif and Fouda (1976) reported similar results.

It is worth mentioning that some plankton feeding fishes caught by purse seining in the Red Sea and also in the Indo-Pacific area have a higher protein content, e.g., *Chrysophrys haffara* (23.13 percent); Marinkovic and Zei (1959) reported similar results. Again, we found that some surface feeding fishes, e.g., *Hemirhamphus marginatus* and *Lutjanus fulviflamma*, have a higher protein content, and a fat content >1.2 percent. This conclusion agrees reasonably well with Van Wyk (1944) that the surface fishes are higher in fat and protein content than deep-water species.

Acknowledgment

The author expresses his sincere thanks to S. C. Chenoda, Tanta University, Tanta, Egypt for the identification of fish species and determination of their ages.

Literature Cited

Al-Kholy, A. A. (editor). 1972. Aquatic resources of the Arab countries. Alecso Sci. Monogr. Ser. [in Arabic], Cairo, 452 p.

Biot, M. 1807. Untersuchngen über die luft in der Schwimmennblase der Fische. Ann. Phys., Lpz. 54, 41 p.

Dyer, W. J., H. V. French, and J. M. Snow. 1950. Proteins in fish muscle I. Extraction of protein fractions in fresh fish. J. Fish Res. Board Can. 7(10):585-593.

El-Saby, M. K. 1934. Dietetic value of certain Egyptian food fishes., Rapp. Comm. Int. Mer Medit. 8, 127 p.

FAO. 1981. The prevention of losses in cured fish. FAO Fish. Tech. Pap. 219, 87 p.

Giménez, J. C. 1934. Revista el Valor alimenticio del pescado. Ann. Soc. esp. Fis. Quim. 32, 86 p.

Hinard, G. 1931. Valeur alimentair du Poisson de mer, des crustacés et mollusques marins comestibles. Rev. Trav. Off. Pêches marit. 4(4):1-425.

Latif, A. F. A., and A. M. A. Fouda. 1976. Proximate composition of some Red Sea fishes. Bull. Inst. Oceanogr. Fish. Egypt 6:55-81.

Marinkovic, M., and M. Zei. 1959. The nutritive value of fish flesh considered in relation to the ecology of fishes. Bull. Sci. Yugosl. 4, 110 p.

Milone, U. 1896. Composizione, valore nutritivo ed assimilalilita della carne muscolar dei pesci. Boll. Soc. Nat. Napoli 10, 311 p.

Morin, B. 1822. Examen chimique de L'eperlan, Salmo eperlanus, L. J. Pharm. Chim., Paris 8, 61 p.

Priestly, J. 1790. Experiments and observations on different kinds of air, Vol. 2. Thomas Pearson, Birmingham, 472 p.

Snow, J. M. 1950. Proteins in fish muscle. II. Colorimetric estimation of fish muscle protein. J. Fish. Res. Board. Can., 7(10): 594-598.

Stansby, M. E. 1962. Proximate composition of fish. *In* E. Heen and R. Kreuzer (editors), Fish in nutrition, p. 55-60. Fish. News (Books) Ltd., Lond.

Van Wyk, G. F. 1944. South African fish products. VIII. Composition of flesh of Cape fish. J. Soc. Chem. Ind. Lond. 63, 357 p.

Vinogradov, A. P. 1953. The elementary chemical composition of marine organisms. Sears Found. Mar. Res. 2, 647 p.

Walker, G., and A. Youngson. 1975. The biochemical composition of *LEPAS ANATIFERA* (L.) cement (Crustacea: CIRRIPEDIA). J. Mar. Biol. Assoc. U.K. 55:703-707.

Waters, M. E. 1982. Chemical composition and frozen storage stability of spot, *Leiostomus xanthurus*. Mar. Fish. Rev. 44(11):14-22.

Weigelt, C. 1891. Die Abfaller der Seefischerei; experimentelle Untersuchungen uber deren Natur, Menge, Verarbeitung und Verwertung. (Sonderbeilage zu den Mitteilungen der Sektionen F. Kusten und Hochseefischerei.)-Moeser, Berlin, 115 p.

Zaitsev, V., I. Kizevetter, L. Laqunov. T. Makarava, L. Minder, and V. Podsevalov (editors). 1969. Fish curing and processing. MIR Publ., Moscow, 722 p.

Assessing the Accuracy of a Method to Determine the Amount of Minced Fish in Mixed Mince-Fillet Fish Blocks

J. PERRY LANE, JOHN J. RYAN, and ROBERT J. LEARSON

Introduction

Some domestic producers of fish sticks and portions have expressed an interest in using fish blocks made from fillets and minced fish in place of the more traditional all-fillet fish blocks. Since the United States Standards for Grades of Frozen Fish Blocks have no provision for grading mixed blocks, such products could not be graded under the U.S. Department of Commerce Voluntary Fishery Product Inspection Program.

As a result, the Gloucester Laboratory of the National Marine Fisheries Service's Northeast Fisheries Center, preparing agency for U.S. Grade Standards for Fishery Products, began work to develop a method for determining the amount of minced fish in a mixed block. This effort was undertaken in collaboration with an industry-government technical working group on fish blocks. The first step was to gather information on existing methods and evaluate them for practicality of application (Lane and Connors, 1984). The method selected as the most promising was called, for purposes of identification, the "Modified Norwegian" method.

Once it was determined that this method appeared practical for commercial use, the next step was to evaluate its accuracy. Further preliminary work with the method resulted in a few minor changes in procedure. This report presents the results of testing the revised method on fish blocks of known proportions of minced fish and fillets.

The authors are with the Gloucester Laboratory, Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Emerson Avenue, Gloucester, MA 01930.

Materials

Five hundred pounds of scrod cod, *Gadus morhua*, (1.5- to 2.5-pound fish) fillets were obtained from a local processor. One hundred pounds of fillets were put through a Yanagiya[1] meat-bone separator with 5 mm holes to produce the minced fish.

A total of 90 5-pound fish blocks were prepared in the laboratory. The 5-pound units were used for reasons of economy rather than the standard 16.5-pound block size used by industry. Except for the block size, we attempted to duplicate the commercial fish block as closely as possible. Since most fish blocks contain 0.5 percent tripolyphosphate (TPP) as a moisture retainer, a stock solution of TPP was made by dissolving 700 g of TPP in 8.3 l of distilled water to give a 7.77 percent TPP solution. The solution was added at the rate of 156 g per 5-pound block. The weight of the solution was not used in calculating either true input percent minced fish nor in the subsequent calculation of the recovered minced fish.

The fillets were cut into about 3 pieces each to approximate the surface area of a commercial 16.5 pound block. The fillets and minced fish were weighed to the nearest 0.25 ounce. The fillets were then placed in a container and the TPP solution was added and mixed by hand for 15 seconds. At the end of this mixing time there was no visible free TPP solution remaining in the container. Next, the minced fish was added and mixing continued for another 75 seconds.

The entire mixture was packed in 5-pound wax-impregnated boxes and placed in a plate freezer frame. When a frame was filled with 4 boxes, it was placed in a 34°F cooler. It required 2 hours to prepare 12 frames, or 48 boxes, the capacity of the plate freezer. At this time all 12 frames (48 boxes) were placed in the plate freezer at −40°F plate temperature. The blocks were removed after 3 hours, taken out of the frames, and stored at −20°F. A second batch consisting of 42 blocks was made, frozen, and stored in the same manner for a total of 90 5-pound blocks.

The input weight of minced fish and fillets for each block was recorded. Thirty blocks were made with 15 percent mince, thirty with 20 percent, and thirty with 25 percent minced fish. After being stored for one week, 10 blocks were selected at random from each of the three lots: 15, 20, and 25 percent. This procedure was repeated a second time resulting in 3 randomly selected lots of 30 blocks each. For the next three consecutive days, three different inspectors—two industry members from the technical working group and one person from the Gloucester Laboratory—each examined 30 blocks according to the following procedure.

Procedure

Principle

A fish block is air thawed, drained, and the weight determined. The block

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

is immersed in a cold-water bath and the fillets are separated from the mince by hand. The fillets are placed on a perforated tray. The remaining water in the bath is poured through a sieve and any fillet pieces are removed from the minced fish and added to the tray. The fillets are drained for 15 minutes and weighed. The amount of minced fish is calculated from the drained weight of the block and the drained weight of the fillets.

Apparatus

1) Shallow tray large enough to hold one fish block for thawing,

2) Container of sufficient size to hold a fish block and 5 gallons of water,

3) Perforated drain tray with 3-8 mm holes covering the entire bottom, and a

4) Balance or scale sensitive to 0.25 ounce (7 g).

Determination

The sample size is an entire fish block. Thaw the sample on a preweighed tray in air at ambient (room) temperature (generally this takes overnight). After the block has been thawed completely, it should not be held for more than 8 hours before examination.

Drain the exuded fluid (thaw drip) by inclining the tray at an angle. Determine the weight of the drained fish flesh (weight = *A*) using a scale of adequate capacity with a sensitivity of 0.25 ounce (7 g). All blocks should be weighed at the same time of initial drained-weight determination. (For this study a second drained weight was obtained at the time each individual block was examined.)

Immerse the drained flesh in a tub of cold tap water (50-70°F). (Use a ratio of 2 parts water to 1 part fish by weight.) Separate the fillets by hand and wash the minced fish flesh from the fillets in the tub. Place the washed fillets on the upper section of a preweighed tray with 3-8 mm holes covering the entire bottom of the tray. Incline the tray at an angle (17-20°) to facilitate draining. Pour the water from the tub containing the minced fish and small pieces of fillets through a U.S. No. 8 Standard sieve. Remove the fillet pieces from the sieve and place them on the drain tray with the fillets. Allow the fillets and pieces to drain for 15 minutes. Remove any excess wash water from the lower section of the tray, then weigh the drained fillets (weight = *B*) using a scale of adequate capacity with a sensitivity of 0.25 ounce (7 g).

Calculations

1) Net weight of sample (*A*) is the thawed, drained fish block obtained initially for Determination 1 or obtained at the time the individual block was examined for Determination 2;

2) Net weight of fillets (*B*) is the weight of the fillets and fillet pieces after 15 minutes drain time;

3) Percent minced fish (*M*) =

$$\frac{\text{Net weight of sample } (A) - \text{net weight of fillets } (B)}{\text{Net weight of sample } (A)} \times 100, \text{ or}$$

$$M = \frac{A - B}{A} \times 100.$$

Results and Discussion

After the 10 blocks from each lot of 15, 20, and 25 percent mince were randomly selected for each of three inspectors, the order in which each inspector examined the blocks was also randomized. The frozen blocks were weighed and placed on trays and left at ambient temperature (71-77°F) for 12 hours. This was done on 3 consecutive days with one inspector doing the examination each day. This was to determine the amount of variation in results among different examiners.

At the end of the 12-hour thawing period, the blocks were drained and the weight was determined for all 30 blocks. The blocks were then placed back on the trays and returned to a cooler at 35°F. The blocks were then removed one at a time for separation of mince and fillets. An assistant then obtained the drained weight of each block a second time and placed the block in 1.25 gallons of cold tap water (63-68°F) in an aluminum tub where the fillets were separated from the minced fish by the inspector. The assistant did all the weighing, leaving the inspector free to do the actual separations. Two drain trays were used for the fillets so it was not necessary to wait for the 15-minute drain time to be completed before starting the next block.

The reason for obtaining the drained weight of the block twice was that in preliminary trials it was noted that the blocks continued to exude fluid (thaw drip) after the initial weighing. It required from 5 to 5.75 hours for the inspectors to complete the examination of the 30 5-pound blocks. The percent mince was calculated twice to see if the requirement that the drained weight of all blocks be taken prior to beginning the examination was necessary to determine the actual percent of minced fish present, or if the thaw drip that accumulated during the examination period had little or no effect on the results.

The actual input percent of minced fish for the 15 percent lot ranged from 14.5 to 15.4 percent with the mean 15.0 percent. The true range for the 20 percent lot was 19.9-20.2 percent with the mean 20.0 percent. For the 25 percent lot the range was from 24.8 to 25.3 percent and the mean was 25.0 percent. Table 1 compares the combined results from the three inspectors with the actual input of minced flesh. Determination 1 uses the initial drained weight of the blocks and Determination 2 uses the drained weight of the blocks obtained at the time of examination.

The greatest deviation from the true lot mean was 1.0 percent for the 20 percent lot under Determination 1. The means obtained using Determination 2 were closer to the input means than those obtained using the initial drained block weights under Determination 1. This would indicate that the procedure requirement that all drained block weights be determined prior to the beginning of the separation of mince from fillets is not

necessary. Not only is it not necessary, but the accuracy of the final calculations for percent minced fish is slightly less than the results obtained by weighing the drained blocks individually at the time of examination.

The other statistical parameters, standard deviation, variance, and range, were all greater for the inspectors' test results than for the actual input, but were remarkably consistent among the three lots. There was very little difference in these parameters between Determination 1 and 2.

As a further check on the inspectors ability to successfully determine the actual amount of minced fish using this method, the results from all three lots were combined and compared with the combined input values. These results are given in Table 2.

The statistical results reinforce the conclusion made for Table 1. The Determination 2 overall mean of 20.2 percent is closer to the true mean, 20 percent, than the mean of 20.7 percent found using Determination 1. Both the test standard deviation and variance are closer to the input figures than was the case when the three lots were considered separately in Table 1. Since the Determination 1 results are not as accurate as those obtained under Determination 2, only the results from the latter will be given for the remainder of this report.

Two other points of interest in determining the suitability and accuracy of this method as a means of determining the amount of minced fish in a mixed mince-fillet block are the amount of variation among inspectors and whether the results are affected by the amount of the minced fish in the block. Comparison of the statistical evaluation for the three inspectors and the three lots (levels of minced fish) with the input results is made in Table 3.

In all but one instance the means for each inspector for all three lots were within ± 1 percent of the true mean. The one exception was inspector two for lot two (20 percent) where the difference was 1.1 percent.

For lot one, the range of means for the three inspectors was from 14.4 to 15.7 percent, a spread of 1.3 percent. For lot two it was from 19.9 to 21.1 percent, a spread of 1.2 percent, and for lot three, from 24.6 to 25.2 percent, a 0.7 percent spread. It should be noted that there was considerable variation in the amount of experience the three inspectors had in doing this type of analysis. One inspector had very limited experience, one moderate experience, and one extensive experience. The experience level had no relationship with the accuracy of the results. Even with the variation in background the agreement among the three inspectors was very high.

As for the effect of level of minced fish in the blocks, it apears to have little, if any, bearing on the accuracy of the results. This would indicate that at least in the range of 15-25 percent minced fish this method would be acceptable.

To further compare the agreement among the inspectors, the data from all three lots were combined for each inspector and compared with combined input data. The statistical comparison appears in Table 4. The agreement among the 3 inspectors was even more striking when the data from the three lots were combined with a range of means of only 1.0 percent, from 19.6 to 20.6 percent. The greatest test difference between the combined mean for any one inspector and the true combined mean was only 0.6 percent for inspector number three. Inspector number one was within 0.4 percent and inspector two was within 0.3 percent. The raw data for both input and recovery are shown in Tables 5-7.

Table 1.—Comparison of combined inspectors' determination of percent minced fish at three levels with actual input (N = 30)[1].

	Determination 1			Determination 2			Actual Input		
Item	15%	20%	25%	15%	20%	25%	15%	20%	25%
Mean	15.6	21.0	25.3	15.0	20.7	25.0	15.0	20.0	25.0
S.D.	1.38	1.59	1.64	1.43	1.66	1.60	0.56	0.09	0.11
Variance	1.85	2.45	2.60	1.98	2.65	2.46	0.31	0.01	0.01
Spread	5.5	6.6	6.6	5.6	6.8	6.5	0.9	0.3	0.6
Range	12.3-17.8	17.2-23.8	22.7-29.3	11.7-17.3	16.7-23.5	22.4-28.9	14.5-15.4	19.9-20.2	24.7-25.3

[1]All figures are percent minced fish.

Table 2.—Comparison of the combined inspectors' results from all three lots with actual input (N = 90)[1].

Item	Determination 1	Determination 2	Actual input
Mean	20.7	20.2	20.0
S.D.	4.28	4.39	4.11
Variance	18.1	19.1	16.72
Spread	17.0	17.2	10.8
Range	12.3-29.3	11.7-28.9	14.5-25.3

[1]All figures are percent minced fish.

Table 3.—Statistical comparison of individual inspectors and actual input of minced fish percent for three levels of minced fish: Determination 2 results[1].

Lot	Insp.1 (N = 10)	Insp. 2 (N = 10)	Insp. 3 (N = 10)	Actual input (N = 10)
No. 1 (15%)				
Mean	14.4	14.8	15.7	15.0
S.D.	1.46	1.30	1.36	.56
Var.	1.93	1.53	1.67	.31
Spread	5.2	4.2	3.5	.9
Range	11.7-16.9	12.2-16.4	13.8-17.3	14.5-15.4
No. 2 (20%)				
Mean	19.9	21.1	21.0	20.0
S.D.	1.68	1.57	1.59	.09
Var.	2.53	2.22	2.28	.01
Spread	6.5	5.2	5.2	.3
Range	16.7-23.2	17.9-23.1	18.3-23.5	19.9-20.2
No. 3 (25%)				
Mean	24.6	25.1	25.2	25.0
S.D.	2.14	1.06	1.50	.11
Var.	4.11	1.01	2.03	.01
Spread	6.5	3.7	4.3	.6
Range	22.4-28.9	23.5-27.2	23.4-27.7	24.7-25.3

[1]All figures are percent minced fish.

Table 4.—Statistical comparison of combined data from three lots for the three inspectors with combined input data (Determination 2)[1].

Item	Insp.1 (N = 30)	Insp. 2 (N = 30)	Insp. 3 (N = 30)	Actual input (N = 90)
Mean	19.6	20.3	20.6	20.0
S.D.	4.55	4.47	4.22	4.11
Var.	20.0	19.3	17.2	16.72
Spread	17.2	15.0	13.9	10.8
Range	11.7-28.9	12.2-27.2	13.8-27.7	14.5-25.3

[1]All figures are percent minced fish.

Conclusions

The minced fish recovery method reported in this paper was selected over three other methods evaluated as being the most practical in terms of ease of application, equipment required, and time of completion. The purpose of this study was to evaluate the method for accuracy using laboratory prepared 5-pound fish blocks with three levels of minced fish. The determinations were made on 10 randomly selected blocks from each of the three lots (levels of minced

Table 5.—Input data and results of inspectors' examination of 5-pound mixed fillet-mince fish blocks, Lot 1, 15 percent mince level.

	Input				Inspector results (Determination 2)			
Block No.	Fillet weight[1]	Mince weight[1]	Percent mince	Insp. no.	Drained block weight	Fillet weight	Mince weight[2]	Percent mince
1	67.75	12.25	15.3	1	81.25	70.75	10.50	12.9
2	68.00	12.0	15.0	2	82.25	72.25	10.0	12.2
3	68.00	12.25	15.3	3	79.0	67.25	11.75	14.9
4	68.0	12.25	15.3	1	81.0	71.50	9.50	11.7
5	68.0	12.0	15.0	1	81.0	69.25	11.75	14.5
6	67.75	11.50	14.5	1	81.50	70.0	11.5	14.1
7	68.00	11.75	14.7	1	80.00	66.50	13.5	16.9
8	68.00	12.25	15.3	3	82.50	68.50	14.0	17.0
9	68.00	11.75	14.7	3	83.25	69.50	13.75	16.5
10	68.25	12.0	15.0	2	83.50	72.25	11.25	13.50
11	67.50	12.25	15.4	3	80.00	66.50	13.50	16.90
12	67.25	12.0	15.0	2	83.50	72.25	11.25	13.5
13	68.00	12.0	15.0	2	82.50	69.25	13.25	16.1
14	67.75	12.0	15.0	2	82.50	69.0	13.50	16.4
15	67.75	12.0	15.0	3	82.25	69.75	12.50	15.2
16	68.25	12.25	15.2	1	83.25	70.0	13.25	15.9
17	68.00	12.25	15.3	2	81.50	68.75	12.75	15.6
18	68.00	12.25	15.3	3	81.50	70.25	11.25	13.8
19	67.75	11.75	14.8	3	79.50	65.75	13.75	17.3
20	68.00	12.0	15.0	3	81.75	68.0	13.75	16.8
21	67.75	11.75	14.8	2	78.25	67.0	11.25	14.4
22	68.25	12.0	15.0	1	80.0	67.75	12.25	15.3
23	68.00	11.75	14.7	2	76.50	65.25	11.25	14.7
24	68.00	12.0	15.0	2	77.50	66.0	11.50	14.8
25	67.75	11.75	14.8	1	79.75	68.0	11.75	14.7
26	68.25	12.0	15.0	2	79.25	66.50	12.75	16.1
27	68.00	11.75	14.7	1	78.75	67.0	11.25	14.4
28	68.00	12.0	15.0	3	76.25	65.75	10.50	13.8
29	68.00	11.75	14.7	1	77.25	66.5	10.75	13.9
30	68.00	12.0	15.0	3	78.0	66.5	11.50	14.7

[1]All weights in ounces.
[2]Mince weight determined by difference.

Table 6.—Input data and results of inspectors' examination of 5-pound mixed fillet-mince fish blocks, Lot 2, 20 percent mince level.

	Input				Inspector results (Determination 2)			
Block No.	Fillet weight[1]	Mince weight[1]	Percent mince	Insp. no.	Drained block weight	Fillet weight	Mince weight[2]	Percent mince
31	63.50	16.0	20.1	3	79.0	63.0	16.0	20.3
32	64.0	16.0	20.0	3	78.75	62.75	16.0	20.3
33	64.0	16.0	20.0	3	80.25	64.25	16.0	19.9
34	64.25	16.25	20.2	2	82.50	64.25	18.25	22.1
35	64.0	16.0	20.0	3	81.75	62.50	19.25	23.5
36	64.0	16.0	20.0	1	80.0	64.0	16.0	20.0
37	64.0	16.0	20.0	2	82.25	64.5	17.75	21.6
38	64.0	16.0	20.0	2	82.0	64.25	17.75	21.6
39	64.0	16.0	20.0	2	84.0	65.5	18.50	22.0
40	64.0	16.0	20.0	3	82.0	63.75	18.25	22.6
41	64.25	16.0	19.9	3	81.75	66.75	15.0	18.3
42	64.0	16.0	20.0	1	80.75	65.0	15.75	19.5
43	64.25	16.0	19.9	1	82.0	66.75	15.25	18.6
44	64.25	16.0	19.9	1	80.25	64.25	16.0	19.9
45	64.0	16.0	20.0	1	81.75	62.75	19.0	23.2
46	64.0	16.0	20.0	1	80.0	63.0	17.0	21.3
47	64.0	16.0	20.0	3	80.75	64.75	16.0	19.8
48	64.0	16.0	20.0	1	82.0	66.0	16.0	19.5
49	64.0	16.0	20.0	1	79.50	66.25	13.25	16.7
50	64.25	16.0	19.9	2	81.0	66.50	14.50	17.9
51	64.0	16.0	20.0	2	81.50	65.25	16.25	19.9
52	64.0	16.25	20.2	2	82.50	65.50	17.0	20.6
53	64.0	16.0	20.0	1	81.25	64.75	16.50	20.3
54	64.0	16.25	20.2	1	83.0	66.50	16.50	19.9
55	63.75	16.0	20.1	2	81.50	65.25	16.25	19.9
56	64.25	16.25	20.2	2	83.75	64.75	19.0	22.7
57	64.0	16.0	20.0	3	79.75	62.75	17.0	20.8
58	64.0	16.0	20.0	3	82.0	63.50	18.5	22.6
59	64.0	16.0	20.0	3	80.50	63.0	17.5	21.7
60	64.0	16.0	20.0	2	83.25	64.0	19.25	23.1

[1]All weights in ounces.
[2]Mince weight determined by difference.

Table 7.—Input data and results of inspectors' examination of 5-pound mixed fillet-mince fish blocks, Lot 3, 25 percent mince level.

	Input				Inspector results (Determination 2)			
Block No.	Fillet weight[1]	Mince weight[1]	Percent mince	Insp. no.	Drained block weight	Fillet weight	Mince weight[2]	Percent mince
61	60.25	20.0	24.9	3	80.25	61.5	18.75	25.5
62	60.0	20.0	25.0	2	81.25	60.5	20.75	25.5
63	60.0	20.0	25.0	1	80.25	62.25	18.0	22.4
64	59.75	20.0	25.1	2	81.50	61.25	20.25	24.2
65	60.0	20.0	25.0	3	80.25	58.0	22.25	27.7
66	60.0	20.0	25.0	2	81.75	61.50	20.25	24.8
67	60.0	20.0	25.0	2	82.50	61.50	21.0	25.5
68	60.0	20.25	25.2	1	81.25	62.75	18.50	22.8
69	59.75	20.25	25.3	1	81.0	60.25	20.75	25.6
70	60.0	20.0	25.0	1	81.0	62.50	18.50	22.8
71	60.0	20.0	25.0	3	81.25	60.25	21.0	25.8
72	60.0	20.0	25.0	1	79.25	60.75	18.50	23.3
73	60.0	20.0	25.0	2	81.50	61.0	20.50	25.2
74	60.0	20.0	25.0	2	80.75	61.25	19.50	24.1
75	60.0	20.0	25.0	2	80.25	60.50	19.75	24.6
76	60.0	20.0	25.0	1	81.25	62.75	18.50	22.8
77	60.0	20.0	25.0	2	80.0	58.25	21.75	27.2
78	60.0	20.0	25.0	3	78.25	59.75	18.50	23.6
79	60.0	20.25	25.2	1	78.50	58.5	19.75	25.5
80	60.0	20.0	25.0	2	80.0	59.25	20.75	25.9
81	60.25	20.0	24.9	3	78.25	58.75	19.50	24.9
82	60.0	20.0	25.0	3	79.75	60.75	19.0	23.8
83	60.25	20.0	24.9	3	79.0	58.50	20.50	25.9
84	60.0	20.0	25.0	3	81.25	60.25	21.0	25.8
85	60.0	20.25	25.2	1	78.75	56.0	22.75	28.9
86	60.0	20.0	25.0	1	81.25	61.0	20.25	24.9
87	60.0	20.0	25.0	3	81.0	59.0	22.0	27.2
88	60.25	20.0	24.9	2	84.0	64.25	19.75	23.5
89	60.25	19.75	24.7	1	81.25	59.5	21.75	26.7
90	60.0	19.75	24.8	3	81.75	62.0	19.75	24.2

[1]All weights in ounces.
[2]Mince weight determined by difference.

fish of 15, 20, and 25 percent) by three inspectors.

The results indicate that the method is accurate within a practical range of ±1.1 percent and that the agreement among inspectors was very high. The level of minced fish, within the range tested of 15-25 percent, had no appreciable effect on the accuracy of the test results or the uniformity of recovery of minced fish among the three inspectors.

Based on these findings, our future work will use commercial size (16.5-pound) fish blocks. The blocks will be hand-made in the laboratory and contain a known level of minced fish. These blocks will be examined by several collaborators using their own facilities and the method modified as agreed to by the methods committee of the technical working group on fish blocks.

Literature Cited

Lane, J. P., and T. J. Conners. 1984. Evaluation of methods to determine the proportions of fillets and minced fish flesh in mixed fish blocks. Mar. Fish. Rev. 46(2):36-39.

U.S. 1983 Shrimp Catch Down, Imports Up

U.S. landings of shrimp in 1983 were down from the previous year, while imports and consumption reached record levels (Table 1). Prices averaged slightly lower to slightly higher in 1983 compared with a year earlier but most were 10-24 percent lower in December 1983 than a year earlier. Prices of the largest sizes were strongest, and prices of middle sizes were weakest.

Gulf and South Atlantic landings were 141 million pounds (heads off) in 1983, down 5 percent from 1982, and 12 percent below the 1978-82 average. The value was $485 million, down 0.1 percent, according to preliminary estimates. The largest drop occurred in Louisiana. Among species, browns were down significantly, while whites and pinks were up somewhat.

U.S. imports of fresh and frozen shrimp were a record 388 million pounds (heads off) in 1983, up 28 percent from a year earlier and 50 percent above the 1978-82 average. Imports of all shrimp totaled 341 million pounds (product weight), valued at $1,224 billion. Imports from Mexico were up 5 percent to 84.6 million pounds ($384 million). Imports from Ecuador advanced sharply—up 42 percent—to 51.4 million pounds ($219 million). Based primarily on shrimp farming, imports from Ecuador grew from averages of 6.7 million pounds in 1968-72 and 21.1 million pounds in 1978-82. Counting Ecuador alone, aquaculture represented perhaps 13 percent of U.S. imports of shrimp in 1983, and future supplies from shrimp farms will be much larger.

Consumption of fresh and frozen shrimp in 1983 reached a record 481 million pounds, 16 percent above 1982, and 30 percent above the 1978-82 average. Meanwhile, inventories of frozen shrimp were 57 million pounds (heads off) at the end of 1983, 15 percent above a year earlier, but 5 percent below the 1978-82 average. The Gulf pack of canned shrimp rose 27 percent to 12 million pounds (heads off).

Ex-vessel and wholesale prices of most Gulf shrimp trended downward in the second half of 1983. Although prices of larger shrimp began turning upward in the last quarter, most prices closed lower in 1983 than in 1982. Wholesale prices of Gulf browns at New York were 4-18 percent lower in December 1983 than a year earlier, except for under 15's, which were 0.5 percent higher. Ex-vessel prices of western Gulf shrimp were 10-22 percent lower. The greatest declines were in the middle sizes. For the year, ex-vessel and wholesale prices averaged 5.7 percent higher and 1.8 percent lower.

Table 1.—U.S. supply and use of fresh and frozen shrimp, 1982-83[1].

Item	Supply[2] 1982	1983
Beginning inventory	52.4	49.2
Landings[3]	149.2	141.2
Imports	302.4	388.0
Total supply	504.0	578.4
Ending inventory	49.2	56.8
Exports	31.1	28.3
Canned pack[4]	9.6	12.2
Apparent consumption	414.1	481.1

[1]Some data preliminary; totals from unrounded data.
[2]Million pounds (heads off).
[3]Gulf and South Atlantic only.
[4]Gulf only.

Southeast Region Tops U.S. Fisheries Landings

Commercial fish landings in the U.S. Southeast Region for 1983 resulted in more fish worth more money than any other part of the United States, according to Jack T. Brawner, Director, NMFS Southeast Regional Office, St. Petersburg, Fla. The Southeast landings were 3.2 billion pounds, representing 42 percent of the total U.S. landings of 7.7 billion pounds, according to NMFS figures. Southeast Region landings were valued at $940 million, representing 36 percent of the total $2.6 billion in U.S. commercial landings. The Southeast Region commercial landings figures cover the states of Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, North and South Carolina, Puerto Rico, and the U.S. Virgin Islands.

Landings reported from the Gulf of Mexico were 2.4 billion pounds valued at $616 million, representing 31 percent of the U.S. landings and 24 percent of the total U.S. value. These figures reflect the gradual and continued increase in Gulf landings. Menhaden, an industrially important fish used mainly for fish meal, was the Gulf leader in volume of landings, yielding a record 2 billion pounds in 1983. Shrimp was the king in value, with a price tag of $417 million. Although substantial, shrimp landings of 198 million pounds were lower in 1983 than the previous 2 years.

Cameron, La., was the leading U.S. fish port in volume of landings, followed by Pascagoula-Moss Point, Miss.; Empire-Venice and Dulac-Chauvin, La.; and Los Angeles, Calif. Shrimp and menhaden were the principal species landed in these ports, except for Los Angeles, where tuna was the principal species.

Louisiana led all states in volume with record landings of 1.8 billion pounds; second was Alaska, with 964 million; followed by Virginia, 751 million.

New England 1983 Fishery Landings and Values Told

Atlantic cod, *Gadus morhua*, was again in 1983 the most landed fish in the five coastal New England states, according to preliminary National Marine Fisheries Service (NMFS) data. Commercial fisherman landed 112 million pounds of the species last year (Table 1). The large cod landings "stem from a redirection of effort by fisherman to catch cod—mostly due to a large decrease in the amount of haddock available to fisherman," according to Frederic Serchuk, NMFS cod biologist.

Haddock, *Melanogrammus aeglefinus*, landings have dropped from 55 million pounds in 1981 to 45 million pounds in 1982, and to 33 million pounds in 1983. According to William Overholtz, NMFS haddock biologist, the outlook for haddock is "continued declines until 1986, with no signs yet of any recovery after that."

Other major species showing increased landings last year were yellowtail flounder, *Limanda ferruginea*, up from 44 million pounds in 1982 to 69 million pounds in 1983, and American lobster, *Homarus americanus*, up from 38 million pounds to 42 million pounds in 1983.

Major species showing decreased landings were Atlantic herring, *Clupea harengus harengus*, down from 73 million pounds in 1982 to 51 million pounds in 1983, and sea scallops, down from 16 million pounds of meats in 1982 to 14 million pounds of meats in 1983. Even though scallop landings decreased, the dockside value increased from $57 million to $78 million due to much higher prices. Overall, total landings increased from 687 to 711 million pounds, with their value also increasing from $374 million to $435 million.

Table 1.—Species landings (in million pounds) and values (in million dollars) data for New England.

	1982		1983	
Species	Landings	Value	Landings	Value
Atlantic cod	104	$37	112	$38
Yellowtail founder	44	25	69	34
Atlantic herring	73	4	51	3
American lobster	37	85	42	101
Haddock	45	22	33	19
Sea scallops[1]	16	57	14	78
All others	368	144	390	162
Total	687	$374	711	$435

[1]Data for meats only.

Table 2.—Port landings (in million pounds) and values (in million dollars) data for New England.

	1982		1983	
Port	Landings	Value	Landings	Value
Gloucester, MA	147	$44	151	$ 38
New Bedford, MA	95	83	112	109
Pt. Judith, RI	64	21	62	26
Rockland, ME	50	11	55	12
Portland, ME	66	15	54	16
Boston, MA	28	13	24	11

Table 3.—State landings (in million pounds) and values (in million dollars) data for New England.

	1982		1983	
State	Landings	Value	Landings	Value
Massachusetts	344	$204	377	$245
Maine	217	101	203	108
Rhode Island	113	55	114	66
New Hampshire	8	4	10	4
Connecticut	6	10	8	12

Port Landings, Values

Gloucester, Mass., again landed the most fish of any New England port (Table 2). Its 151 million pounds in 1983 (up from 147 million pounds in 1982) also ranked it seventh nationally. The value of Gloucester's 1983 landings, 38 million dollars, was a drop from 44 million in 1982, but still placed it eighth nationally in that category.

New Bedford, Mass., benefactor of the much higher prices being paid for scallop meats last year, again had the highest valued landings of any New England port. Its $109 million value in 1983 (up from 83 million dollars in 1982) also ranked it first nationally. It easily outdistanced runner-up Los Angeles, Calif., which had an $85 million value. (Los Angeles mostly lands tuna, another high-valued species.) New Bedford's 112 million pounds of landings in 1983 also placed it eighth nationally in that category.

The rankings among six major New England ports in 1983 landings and values, respectively, were Gloucester (1st, 2nd); New Bedford (2nd, 1st); Pt. Judith, R.I. (3rd, 3rd); Rockland, ME (4th, 5th); Portland, ME (5th, 4th); and Boston (6th, 6th).

State Landings, Values

Massachusetts continued to lead New England states in 1983 with 344 million pounds (Table 3), 53 percent of the landings and 56 percent of the value. The rankings of other New England states in 1983 landings and values, respectively, were Maine (2nd, 2nd), Rhode Island (3rd, 3rd), New Hampshire (4th, 5th), and Connecticut (5th, 4th).

Maine was the only state to show a landings decrease—14 million pounds—which was due in part to the 22 million-pound decrease in Atlantic herring landingss off New England last year. According to Vaughn Anthony, NMFS herring biologist, the "failure of herring to move inshore as much as usual during the summer reduced the catch in the coastal weirs and seines." Anthony also pointed to "reduced demand for herring by foreign importers" as another reason for the decreased herring landings.

U.S. East Coast Squid Landings Set New Records

U.S. 1983 commercial landings of squid were a record 61.4 million pounds valued at $14.4 million—an increase of 1.8 million pounds and up 3 percent from the record set in 1982. The value increased $5.3 million (59 percent) compared with 1982. Record landings by the Atlantic Coast fleet offset a 31.5 million pound (88 percent) drop in the west coast squid landings; the climatic effects of the El Niño greatly disrupted the California fishery.

The record Atlantic Coast catch totaled 57 million pounds, as 33.5 million pounds were landed at east coast ports and 23.5 million pounds were sold to foreign processing vessels operating within the U.S. waters under approved joint ventures. The more desirable east coast loligo squid

brought higher ex-vessel prices causing the 59 percent increase in the total value. Strong export markets during 1983 consumed most of the production.

Scientists at the NMFS Northeast Fisheries Center, Woods Hole, Mass., report research vessel abundance indices for Atlantic loligo squid indicated good yields could be expected in 1984 if fishing efforts remained similar to 1983. This is contrasted by the low abundance index for Atlantic illex squid which indicates its current abundance is significantly reduced from its former high levels.

Hard Blue Crab Leads Mid-Atlantic Landings

Hard blue crabs, *Callinectes sapidus*, were again the most-landed seafood in 1983 in the Mid-Atlantic states, according to NMFS preliminary data (Table 1). Commercial fisherman landed 98 million pounds of the species valued at $29 million, during 1983. That was 2 million pounds and $3 million more than in 1982.

Atlantic menhaden were still the most landed finfish in the Mid-Atlantic states; however, that species is not consumed as seafood, but processed into fish meal, oil, and solubles which, in turn, are used in a variety of industrial and commercial applications. Mid-Atlantic landings contributed to the 927 million pounds and $37 million in menhaden landings along the U.S. Altantic coast.

The highest valued seafood species landed in Mid-Atlantic states last year was the sea scallop. Even though landings of scallop meats dropped from 6 to 4 million pounds between 1982 and 1983, the value jumped from $16 million to $32 million, due to the much higher prices being paid for scallop meats.

The only species to decline significantly in landings and value last year was the American oyster. From 1982 to 1983, oyster landings dropped from 20 to 13 million pounds of meats, and value dropped from $33 million to $22 million.

Table 1.—Species landings (in million pounds) and values (in million dollars) for Mid-Atlantic states.

	1982		1983	
Species	Landings	Value	Landings	Value
Hard blue crab	96	$26	98	$29
Surf clam	47	24	52	23
Ocean quahog	31	10	32	10
Summer flounder	11	8	15	10
Squids	11	2	14	4
American oyster	20	32	13	22
Silver hake	10	3	11	3
Scup	9	4	9	4
Weakfish	7	3	7	3
Sea scallop	4	16	6	32

Nineteen Named to Regional Fishery Management Councils

Nineteen individuals have been appointed to the nation's eight Regional Fishery Management Councils by Commerce Secretary Malcolm Baldrige from nominees submitted by the Governors of the States served by each Council. The 3-year appointments took effect in August.

Named to the Caribbean Fishery Management Council was Jose Luis Campos, Insurance Broker, John Hancock Mutual Life Insurance Co., Hato Rey, Puerto Rico. Appointed to the Gulf of Mexico Fishery Management Council were Julius Collins, President, J. Collins Trawler-Gulf Shrimp Co., Brownsville, Tex.; William D. Chauvin, Executive Director, American Shrimp Canners and Producers Association, New Orleans, La.; and Frank J. Barhanovich, owner, Latitude Gifts, Biloxi, Miss.

New to the Mid-Atlantic Fishery Management Council are Warren F. Hader, owner and operator, fishing vessel *Devilfish*, Montauk, N.Y.; Robert L. Martin, Attorney, Bellefonte, Pa.; Ricks Savage, Offshore Surf Clam Fisherman, Berlin, Md.; and Joseph J. MacMillan, retired Business Manager from White Cap Seafoods, West Sayville, N.Y. Named to the New England Fishery Management Council were James W. Salisbury, owner and operator, Petit Manan Fisheries, Inc., Milbridge, Maine; James L. Warren, Executive Director, Maine Sardine Council, Brewer, Maine; and Anthony J. Verga, Executive Director, Gloucester Fisheries Commission, Gloucester, Mass.

For the North Pacific Fishery Management Council, new appointees are Henry V. Mitchell, Executive Director, Bering Sea Fishermen's Association, Anchorage, Alaska; and John G. Peterson, Vice Chairman of the Board, Ocean Beauty Seafoods, Inc., Seattle, Wash. New Pacific Fishery Management Council members include James A. Crutchfield, Jr., Professor, Department of Economics, University of Washington, Seattle; and George J. Easley, Administrator, Otter Trawl Commission of Oregon, Astoria.

South Atlantic Fishery Management Council members are Kenneth B. McGovern, Jr., Executive Director, Humane Society of Greater Miami, Inc., Miami, Fla.; and Belton O'Neil Sanders, President, Sanders Transport, Inc., Allendale, S.C. And, appointed to the Western Pacific Fishery Management Council were Wadsworth Yee, President, Grand Pacific Life Insurance Co., Honolulu, Hawaii; and Alika Cooper, Manager, Cooper & Sons, Inc., Hilo, Hawaii.

Yellowfin Tuna Tracked Near Hawaiian FAD's

Richard W. Brill, Leader, Experimental Ecology of Tunas Program at the Honolulu Laboratory of the NMFS Southwest Fisheries Center reports that Kim Holland, Hawaii Institute of Marine Biology; Scott Ferguson, NOAA Corps; Randolph K. C. Chang, Fishery Biologist; and research assistant Lance S. Asagi participated in a highly successful track of a 70 cm fork length (FL) yellowfin tuna, *Thunnus albacares*, off Waianae, Oahu, on the Honolulu Laboratory's research vessel, *Kaahele'ale*. This work is part of a project to determine the short term horizontal and vertical movements of tunas around fish aggregating devices (FAD's).

The fish was caught near the 91 m (50 fm) isobath a few miles off the coast at 9:55 a.m. on 7 October. An ultrasonic depth sensitive transmitter with a 12-day battery was attached to the fish, and on the initial track the fish was followed for 26 hours until it was lost directly off Kaena Point. After returning to Waianae Boat Harbor for refueling and to allow the crew to rest, the *Kaahele'ale* returned to Kaena Point about 12 noon on 9 October. The fish was relocated and tracked until the following morning (10 October) when it returned to the vicinity where it was originally caught.

After the *Kaahele'ale* returned to the Waianae Boat Harbor to refuel and exchange crews, a search for the fish was resumed late in the afternoon of 12 October. The fish was again relocated near the Kaena Point-Makus vicinity and was tracked until the following morning when it again returned to the inshore area near the 91 m isobath where it was originally caught.

The vessel was forced to return to Kewalo Basin on 13 October because of the threat of hurricane Raymond. An attempt to relocate the fish was made on 19 October. Unfortunately, the transmitter had apparently been shed and was lying on the bottom near the 109 m (60 fm) isobath in an area off the coast between Keaau and Kepuli Points.

This very successful mission resulted in three prolonged tracks spanning 6 days. Unprecedented data on yellowfin tuna's horizontal and vertical movements were acquired, and the information obtained has significant implications for the placement and effects of FAD's. This yellowfin tuna showed a predictable behavior pattern that allowed it to be repeatedly relocated for several days after it was originally caught. The fish appeared to have a definite "home range" that included the inshore 91 m isobath. It made significant excursions offshore (well offshore of the present leeward Oahu FAD locations) but returned to the 91 m isobath area at about the same time every day. Also, rapid dives to over 700 m were recorded. These behavior patterns revealed motor, physiological, and nagivational abilities that were previously suspected but undocumented.

The tracking equipment worked extremely well. In particular, the newly installed hydrophone fairing reduced water movement noise so excellent signal reception was possible at boat speeds of 6-7 knots.

Another yellowfin tuna was successfully tracked for 24 hours when a 55 cm FL fish was caught at 7:00 a.m., 17 November, immediately adjacent to fish aggregating buoy S which is located off the Waianae coast of Oahu. The fish remained in the vicinity of buoy S for only a short period and then proceeded via a relatively direct course to fish aggregating buoy V, about 10 miles north of buoy S. The fish remained in the immediate vicinity of buoy V for about 7 hours, until it moved rapidly offshore (west) just before sunset. The fish was followed until about 7:00 a.m. the following day when the tag was shed.

This track conclusively shows that yellowfin tuna will successfully visit fish aggregating buoys that are up to 10 miles apart and that they apparently have the ability to learn buoy locations and directly navigate from one buoy to another. More attempts to track yellowfin tuna for up to 48 hours will continue.

Gulf of Maine Lobster Tagging Program Advances

Results from the first 6 months of a 3-year joint State of Maine-National Marine Fisheries Service lobster tagging and undersea (submersible) research program have been compiled by the NMFS Northeast Fisheries Center. The purpose of this program is to provide information on abundance, migration, growth, and stock interaction between inshore and offshore lobsters in the Gulf of Maine and to better understand the effects of the expanding offshore fishery on the inshore stocks of lobsters. Of primary interest is the role of the central Gulf of Maine lobster stock in providing recruitment to the coastal areas. Does the offshore Gulf of Maine lobster population represent an important part of the broodstock for the inshore population? Do the offshore Gulf of Main deep water basins provide important habitats for a potential broodstock?

In July 1983, 1,002 lobsters were tagged and released in Jordan Basin and Crowell Basin in the central Gulf of Maine. Lobsters ranged in size from 3¼ inches (carapace length) to 6⅜ inches; 65 percent were females and 35 percent were males. The average size of lobsters tagged was 4½ inches. Since July 1983, 319 tagged lobsters have been recaptured, of which 24 were removed from the population (returned to NMFS) and 295 were recaptured between 1 and 4 times.

The 24 lobsters removed from the population had shown extensive migrations both northwest (into the coast of Maine from Pleasant Bay to Cape Elizabeth) and southwest to the Great South Channel and the continental slope near Veatch Canyon. The maximum distance traveled was by a female lobster which covered 198 n.mi. in about 164 days. The average distance traversed by these 24 recaptures was 8 n.mi. averaging 0.20 n.mi. per day.

The remaining 295 recaptures, all released by a single offshore fisherman from Maine, were made in relatively close proximity to the original area of capture and tagging. However, since 30 October, no recaptures were made within a 10 n.mi. radius of the release sites, even though the distribution of fishing effort by this fisherman remained the same.

Of the 651 female lobsters tagged and released in July, 51 percent were berried. The average size of these females was 4¾ inches, ⅜ inch above the average size of all females. Recaptured females had both released eggs and extruded eggs between the times of tagging and recapture.

These preliminary results indicate a high removal rate in the vicinity of the tag and release areas with either an apparent tendency of tagged lobsters

to remain in areas where there are large numbers of lobster traps or a slow rate of migration through tagging areas. Of the 319 lobsters recaptured to date, only 24 were captured outside of a 10 n.mi. radius from the release locations. It is evident from the decline in the recapture rate in the vicinity of the release areas and the distribution of recapture locations that the original stock of tagged lobsters has now dispersed over a very broad area.

In August 1983, a research submersible diving operation was conducted from the R. V. *Johnson*, support vessel for submarine *Johnson-Sea-Link II*. A total of 17 dives were conducted from Georges Basin and the Northeast (Fundian Channel) northward to Jordan Basin. The most significant findings of this exploratory survey were that few lobsters, virtually no classical lobster habitat, and no temporary or permanent shelters (lobster-excavated) were seen in areas known to support, at least seasonally, commercial concentrations of lobsters. The presence of a successful trap fishery would indicate that more lobsters should have been seen. Therefore, it was tentatively concluded that the central Gulf of Maine lobster stock is transient, and it appears that the offshore fishery does not depend on a resident stock.

NEFC Expands Sea Sampling Programs

The NMFS Northeast Fisheries Center (NEFC) initiated an expanded commercial sea sampling program in the Northeast Region in January. This program provides detailed information on catches rather than the landings information normally collected at the dock. The data on discards by species and size are especially valuable. A minimum of 26 trips were proposed for the year covering the fisheries from Maine to Virginia.

The Center has historically been involved in sea sampling on a limited basis. From 1977 through 1983, 53 trips aboard commercial vessels were completed from 20 different ports within the region covering otter trawls for groundfish, gill netters, scallopers, surf clam dredges, the offshore lobster fishery, the red crab fishery, and handliners. The present program represents partial implementation of the third-tier data collection system which was developed by the Northeast Fisheries Task Force in cooperation with the fishing industry.

The first tier of the system corresponds to landings and value data collected from dealers; the second tier corresponds to collection of data from vessel captains on areas fished and fishing efforts for a fishing trip; and the third tier corresponds to the collection of detailed data (catch-effort, discards, lengths-frequencies, samples for ageing, etc.) on a tow-by-tow basis aboard commercial fishing vessels, using NMFS personnel and selected fishermen who agree to keep detailed record books.

Vessel captains and/or owners were contacted and informed of the program through NMFS port agents stationed in the major ports, or through the program coordinator in Woods Hole, and invited to participate. Scientific personnel from the NEFC and port agents have been placed aboard cooperating commercial vessels to collect information during fishing operations.

Sampling of catches from the different vessels, sizes, and gears is expected and various types of fisheries will be included such as mixed groundfish, whiting, shrimp, spiny dogfish, squid, yellowtail, scallops, surf clams, ocean quahogs, swordfish, etc. The program will also provide the opportunity for fisherman and sea samplers to exchange information and views.

Information obtained during the trips will be confidential and the data collected will be integrated into the NEFC data base for fish stock assessments. The assessments are in turn used by the New England and Mid-Atlantic Fishery Management Councils to manage the region's principal fisheries such as haddock, Atlantic mackerel, sea scallops, etc. In addition, the data obtained can be used to quantify fisherman's observations. For example, if the fishermen say that they are discarding a lot of small yellowtail flounder in a certain area, by placing a sea sampler aboard the vessel, NMFS can obtain the data necessary to quantify the percentage of discard.

The first sea sampling off the New England states focussed on the northern shrimp fishery in the Gulf of Maine. The first sea sampling off the Mid-Atlantic states focussed on the squid, silver hake, black sea bass, and scup fisheries.

How Much Squid Do Tunas Eat?

A review of food habit studies of eastern tropical Pacific tunas has been completed by biological aid Lisa Ankenbrandt of the NMFS Southwest Fisheries Center's La Jolla Laboratory, emphasizing information on cephalopod forage and their importance to the predator. Ankenbrandt reports that cephalopods do not appear to be a predominant prey for tunas in the eastern tropical Pacific. Volumetric percentages of prey from all studies consisted of 65.4 percent fishes, 18.1 percent crustaceans, and 16.5 percent cephalopods.

The predominant cephalopod families captured by tunas included Ommastrephidae (*Ommastrephes bartramii*, *Dosidicus gigas*, and *Symplectoteuthis oulaniensis*), Loliginidae, Argonautidae, Octopodidae, Onychoteuthidae, and Enoploteuthidae. Ankendrandt examined variations in the diet, comparing cephalopod importance with that of fishes and crustaceans in terms of volume, numbers, and frequency of occurrence. The percentage of squids to octopods was also compared.

The multiplicity of prey indicates that tunas are nonselective feeders and that stomach contents are probably determined by prey availability in any given area. Tunas and other higher trophic level predators could serve as more efficient samplers of fast swimming epipelagic fauna than conventional sampling gear. Comprehensive food investigations of

these predators provide an alternative method of assessing cephalopod populations in the eastern tropical Pacific Ocean.

Enforcement Officials Seize Spiny Lobsters

More than 5 tons of undersized spiny lobster tails valued at about $100,000 were seized earlier this year in southern Florida during searches conducted by state and Federal authorities following an undercover investigation begun more than a year ago. Officers of the Florida Marine Patrol, National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service seized the illegal lobster tails when ten Federal warrants were executed in a variety of facilities, residences, and vehicles along the gold coast from Ft. Lauderdale through Miami to Key West. The Florida Marine Patrol also confiscated 1,000 pounds of undersized spiny lobsters coming in from the Bahamas through the Miami airport. The searches and seizures began on 29 March.

Also seized in the searches were a pound of cocaine and two illegal firearms. The persons associated with the cocaine and firearms were arrested and will be prosecuted by the state of Florida. Material seized in the searches were to be examined by Federal authorities for purposes of possible prosecution, according to Elton J. Gissendanner, Executive Director of Florida's Department of Natural Resources, and Jack T. Brawner, Director of NMFS's Southeast Region. Both directors termed the illegal fishery activities broadscaled.

Preliminary review of documents seized under the warrants indicates additional suppliers, processors, and distributors will be investigated for illicit trade in undersized spiny lobsters and for excessive glazing of lobster tails in violation of U.S. Food and Drug Administration's (FDA) regulations relating to net weight. Glazing involves dipping or spraying water on the lobster tails and then freezing to provide a protective coating for storage. State and Federal agents say they have seen some lobster tails in which 30 percent of the weight consisted of ice. Brawner indicated that consumers are being cheated by excessive glazing and this information will be turned over to the FDA for action.

The illicit activities violate both state and Federal laws. Florida exercises jurisdiction over waters from the shoreline out to 9 n.mi. on the west coast and out to to 3 n.mi. on the east coast. Federal waters extend from the outer boundary of state waters to 200 n.mi.

The Gulf and South Atlantic Spiny Lobster Fishery Management Plan, developed by the Gulf of Mexico and South Atlantic Fishery Management Councils under the Magnuson Fishery Conservation and Management Act, was implemented by NMFS on 30 June 1982. The plan, which is essentially compatible with regulations enacted by the State of Florida, is designed to prevent depletion of the lobster stocks and increase the yield from the fishery. The management measures set fishing seasons, impose harvesting and gear restrictions, require catch and fishing effort reporting, vessel and gear identification, and set minimum sizes for lobsters.

Spiny lobsters with a carapace length of 3.0 inches or less, or with a tail length of less than 5.5 inches, must be returned immediately to the water unharmed. Live lobsters under the minimum size may be held in a shaded live box aboard a vessel for use as attractants in traps. However, no more than three undersized lobsters for each trap carried on board, or 200 undersized lobsters, whichever is greater, may be retained for such use.

The Lacey Act Amendments of 1981, among other things prohibit the illegal importation of fish, wildlife, or plants as well as the interstate transportation of such illegally possessed or imported products. The Amendments represent an important Congressional mandate to gain control of the massive smuggling and trade in illegally taken fish and wildlife. Violators are subject to both civil and criminal penalties.

The spiny lobster fishery is a high-value fishery and over the years has attracted excessive fishing effort. Recent increases in the harvest and sale of undersized lobsters or "shorts" and the taking of lobsters during the peak spawning period, when there is a closed season, are major problems in the fishery. These activities reduce the yield that could be taken from the fishery and also threaten the ability of the lobster stock to reproduce adequately. Gissendanner and Brawner indicated their agencies will vigorously pursue any illegal spiny lobster operation and will take every action within their authority to protect this valuable resource.

Proximate Composition of Synthetic vs. Real King Crab Legs

Several inquiries concerning the proximate composition of synthetic king crab legs prompted the Utilization Research Division of the NMFS Northwest and Alaska Fisheries Center to analyze a sample of simulated crab legs prepared from pollock produced by Nippon Suisan[1].

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

The proximate composition of the imitation crab legs and the king crab meat is shown in Table 1.

Table 1.—Proximate composition of imitation crab legs and king crab meat.

Item	Proximate composition (%)	
	Imitation crab legs	King crab meat
Moisture	74.61	78.6
Protein (total N × 6.25)	12.35	18.0
Fat	0.06	2.0
Ash	2.68	1.8
Carbohydrate (by difference)	10.30	0

Source: Contributed by Jerry K. Babbitt.

Japan's 1983 Fisheries Catch Sets Record

Japanese fishermen enjoyed a record-high fisheries catch in 1983. The U.S. Regional Fisheries Attache in Toyko reports that Japan's 1983 fisheries harvest totaled 11.9 million metric tons (t), an increase of almost 5 percent over the 1982 catch of 11.4 million t. Japan has successfully maintained its fisheries catch above 10 million t since 1979 (Table 1), and continues to land the world's largest fisheries catch.

Marine Fisheries

Japan's 1983 marine fisheries harvest increased by 4.7 percent to 11.7 million t and accounted for 98 percent of the total catch. The largest increase in 1983 was in the offshore/coastal fisheries catch, which increased by 4.8 percent compared with 1982, from 8.1 million t to nearly 8.5 million tons. The greatest percentage change was in the marine aquaculture catch, which increased by 12.2 percent to nearly 1.1 million t in 1983—nearly five times the inland water harvest and about half the distant-water catch.

Inland Fisheries

Japan's inland fisheries catch comprises less than 2 percent of the total catch and decreased by nearly 4 percent in 1983. The freshwater catch decreased by almost 5 percent and the freshwater aquaculture catch decreased by 2 percent.

Catch By Species

Japan's record high catch in 1983 was largely the result of an increased sardine catch. In 1982, Japan's sardine catch was 3.3 million t, while in 1983 it increased to 3.7 million t and accounted for over 30 percent of the total fisheries catch (Table 2). The two other leading species making up Japan's fisheries catch were Alaska pollock (12 percent of the total) mackerel (7 percent of the total). The mackerel catch increased by 12.1 percent in 1983, but the pollock catch decreased by 8.6 percent. The 135,000 t decrease in the pollock catch was due almost entirely to decreased catch allocations which Japan received from the United States (such allocations were 835,000 t in 1982, but only 731,000 t in 1983). Sardine, Alaska pollock, and Pacific mackerel together accounted for 51 percent of the total 1983 marine catch. Finally, the number of whales harvested by Japan decreased by 7.3 percent in 1983. (Source: IFR-84/51.)

Table 1.—Japan's fisheries catch by major fisheries, 1979-83[1].

Fishery	Catch (1,000 t) 1979	1980	1981	1982	1983[2]	Percent change 1982-83
Marine						
Distant water	2,066	2,167	2,165	2,089	2,114	+ 1.2
Offshore	5,458	5,705	5,939	6,070	8,531[3]	+ 4.8
Coastal	1,953	2,037	2,038	2,072		
Aquaculture	833	992	960	938	1,052	+ 12.2
Subtotal	10,590	10,901	11,103	11,169	11,698	+ 4.7
Inland						
Aquaculture	95	94	92	96	94	– 2.1
Other	136	128	124	122	116	– 4.9
Subtotal	231	221	216	218	210	– 3.7
Grand total	10,590	11,122	11,319	11,388	11,908	+ 4.6

[1]Source: U.S. Regional Fisheries Attache, U.S. Embassy, Tokyo.
[2]Preliminary statistics.
[3]Offshore and coastal breakdowns were not available.

Table 2.—Japan's fisheries catch by species, 1979-83[1].

Fishery	Catch (1,000 t) 1979	1980	1981	1982	1983[2]	Percent change 1982-83
Sardine	1,817	2,198	3,089	3,325	3,731	+ 12.2
Alaska pollock	1,551	1,552	1,595	1,567	1,432	– 8.6
Pacific mackerel	1,414	1,301	908	718	805	+ 12.1
Tunas	363	378	360	372	358	– 3.8
Skipjack tuna	347	377	305	303	373	+ 23.1
Saury	278	187	160	207	240	+ 15.9
Squid, Jpn. flying	213	330	197	182	195	+ 7.1
Salmon	131	123	150	136	161	+ 18.4
Pacific cod	92	97	103	95	105	+ 10.5
Other	4,384	4,579	4,452	4,483	4,508	+ 1.0
Total	10,590	11,122	11,319	11,388	11,908	+ 4.6
	Number of whales					
Whales	4,918	5,191	4,887	4,967	4,606	– 7.3

[1]Sources: U.S. Regional Fisheries Attache, U.S. Embassy, Tokyo, and Ministry of Agriculture, Forestry and Fisheries of Japan.
[2]Preliminary statistics (salmon data do not agree with FAO statistics).

Japan's Surimi Production Up 11 Percent in 1983

Japanese frozen surimi (minced fish meat) production during 1983 amounted to 376,997 metric tons (t), up 10.7 percent from the 1982 total of 340,534 t (Table 1). Of that total, 208,110 t (55 percent) consisted of factoryship-processed production (motherships and large trawlers) and 168,887 t (45 percent) was from land-based production.

Compared with 1982, the 1983 production of factoryship-processed surimi increased 4.8 percent and that of the land-based surimi production was up 18.9 percent. While the 1983 production was the largest in 7 years, it was not a year for overall record production. Fluctuations in the trend of Japan's frozen surimi production for the last 11 years is shown in Table 1.

Meanwhile, Japanese production

of certain surimi-based products increased from 960,000 t in 1982 to 981,000 t in 1983. Production of imitation crab legs and other fish cake increased from 36,000 t to 44,000 t. Imitation crab legs are made with minced Alaska pollock meat (50-60 percent), crab meat or crab paste (some companies claim to have up to 20 percent), and other ingredients. Fried fish cake production grew from 289,000 t in 1982 to 297,000 t in 1983 while steamed fish cakes dropped from 352,000 t in 1982 to 347,000 t in 1983. Production of fish ham and fish sausage increased from 95,000 t to 98,000 t in 1983. (Sources: FFIR 84-8, 13.)

Table 1.—Japanese frozen surimi production, 1972-83. (Source: FFIR 84-8.)

Year	Production (t)			Year	Production (t)		
	Factory ship	Land-based	Total		Factory ship	Land-based	Total
1972	193,500	161,200	354,700	1978	183,012	132,433	315,445
1973	223,600	159,100	382,700	1979	180,401	114,425	294,827
1974	195,300	152,800	348,100	1980	183,232	105,668	288,900
1975	191,200	166,000	357,200	1981	192,264	114,393	306,657
1976	187,000	198,000	385,000	1982	198,534	142,000	340,534
1977	168,823	191,769	360,592	1983	208,110	168,887	376,997

Norway's Fisheries Up Over 1982 Levels

In 1983, as in previous years, most of the Norwegian catch of major fish species was determined by international agreements and national regulations. The total harvest of fish, shellfish, and seaweed amounted to 2,928,600 million metric tons (t), or 11 percent more than in 1982 (Table 1). Pelagic fish, notably capelin, accounted for most of the increase.

Exports of fishery products increased by 25 percent, to Norwegian Kroner (NK) 7.5 billion (US$1.0 billion)[1]. Weak demand abroad for Norway's traditional stockfish and klippfish was more than balanced by increased sales of frozen fillets, fish meal and oil, and cultured salmon. Government fishery subsidies for 1984 remained at the 1983 level of NK 1.1 billion.

The industry complains that these subsidies are too low despite the fact that it will receive an additional NK300 million in state guarantees for selected fishery products. A reduction of catch quotas for the two major fish species (cod and capelin) indicates reduced employment in the Norwegian fishing fleet and fish processing industry in 1984. Long-term prospects appear more promising, due to increasing stocks of herring, cod, and capelin, and growing production of cultured fish.

Fishing Industry

The total catch in 1983 of major species was largely determined by international agreements and national regulations, such as quotas and bans on fishing in certain areas and at certain periods of time. The total allowable catch (TAC) for Arctic cod and cod-like species and for Barents Sea capelin was limited to the quantities stipulated in Soviet-Norwegian agreements, while fishing quotas for major species of fish in the EC zone of the North Sea and adjacent waters were set jointly by Norway and the EC. The Ministry of Fisheries also determined maximum fish quotas for certain types of gear and for individual vessels.

Table 1.—Norway's fishery catch, 1980-83, by species and quantity

Species	Harvest (t)			
	1980	1981	1982	1983[1]
Herring	1,361	10,095	23,449	43,800
Mackerel	76,921	62,098	74,062	75,000
Capelin	1,118,069	1,347,258	1,159,646	1,494,000
Pout	129,525	85,736	169,103	189,000
Whiting	134,973	166,702	170,047	191,000
Cod	281,201	338,882	343,483	276,000
Haddock	68,101	66,071	46,840	24,100
Saithe	176,962	222,183	231,297	220,000
Ling	27,189	23,459	28,403	29,000
Cusk	36,968	30,593	27,368	26,200
Redfish	8,614	9,461	10,220	11,500
Shrimp	44,810	40,970	51,499	75,000
Crab	2,178	2,175	2,074	2,000
Seaweed	126,813	148,365	149,730	150,000
Other	293,782	134,356	153,175	122,822
Total	2,526,985	2,686,958	2,638,136	2,928,600

[1]Preliminary figures for 1983. Totals may not add due to rounding.

Value

The ex-vessel value of the 1983 catch, subsidies included, was NK4.1 billion, up 5.2 percent. Increased catches were mainly recorded for pelagic fish species (capelin, Norway pout, North Sea herring), the bulk of which are reduced to fish meal and oil. The catch of pelagic species amounted to 2,063,000 t, up 21.5 percent over 1982. The catch of cod and other groundfish (haddock, pollock, redfish), which are normally marketed as higher-priced commodities for human consumption, was 608,600 t, or 13.7 percent below the 1982 level. Shrimp, *Pandalus borealis*, reached an all time high of 75,000 t, up 45 percent.

The Barents Sea cod stock is still relatively low following years of overfishing by Norwegian, Soviet, and other trawler fleets. Because of the prevalent sea temperatures and the current age distribution of the cod, the bulk of the cod stock stays largely in the western part of the Barents Sea, which is within Norway's economic zone. Norwegian fishermen, however, were limited in fully exploiting this advantage in 1983. The Ministry of Fisheries (MOF) introduced bans for specified grounds and/or seasons; limitations on the number of fish nets per vessel; maximum catch quotas per vessels, and other restrictions. According to a MOF official, such regulations reduced Norwegian cod landings in 1983 by about 50,000 tons.

[1]In 1983, the average value of US$1.00 was NK7.30.

Exports

Total exports of fishery products reached NK7.5 billion in 1983, an increase of nearly 25 percent. Exports of frozen fillets increased substantially (by 28.5 percent) during the first 10 months of 1983 compared with January-October 1982. This was due to import restrictions in Norway's main markets for stockfish and klippfish (Nigeria, Brazil, Portugal), which prompted Norwegian processors to process as large quantities as possible of cod and cod-like species (haddock, pollock) into frozen fillets in 1983.

Brisk demand for and high prices of fish meal and oil resulted in an export value increase of 47.7 percent and 30.3 percent, respectively. Exports of fish products to the United States almost doubled to NK750 million. Aimed at Norwegian whaling, the environmental groups' boycott actions against the exports of Norwegian frozen fish to the United States did not prevent the U.S. imports of frozen fish fillets and blocks from Norway from increasing slightly in 1983 to 18,000 t.

Fish farming is assuming a significant and rapidly expanding role in the Norwegian fishing industry. During the last decade, fish farm production has increased from 1,000 t to about 17,000 t in 1983. Atlantic salmon, *Salmo salar*, accounts for about three-fourths of this production. Exports of air-freighted fresh salmon to the United States exceeded 2,000 t in 1983. (See "Norwegian Salmon and Trout Farming" by R. Ford, page 28, this issue.)

Fishery Agreements

Norway-U.S.S.R.

Soviet-Norwegian fishery negotiations for 1984 were concluded on 18 November 1983. Of a total allowable catch (TAC) of 260,000 t of cod—80,000 t less than in 1983—Norway was allocated 80,000 t, as well as 40,000 t of coastal cod; the Soviet Union 80,000 t and 40,000 t of Murmansk cod; and third countries 20,000 t. The Soviet Union, however, transfered 60,000 t of its cod quota to Norway (reflecting the fish migration of recent years to Norwegian waters). In compensation, the Soviets were allotted a 385,000 t blue whiting quota (100,000 t less than in 1983) in Norway's economic zone including Jan Mayen. The 1984 haddock TAC was stipulated at 40,000 t, 18,000 t for each country and 4,000 t for third countries. In addition, Norway was allowed to catch 2,000 t of shrimp, *P. borealis* and 18,000 seals in the Soviet economic zone. Of a TAC of 1.5 million t of capelin (400,000 t less than in 1983), Norway was, as in previous years, allowed to catch 60 percent and the Soviet Union 40 percent.

Norway-EC

The EC, on 14 December 1983 approved a fisheries agreement with Norway. As a result of the Norwegian Government's plan to reduce the foreign catch of exclusive Norwegian fish stocks north of the 62nd parallel, the 1984 EC cod quota was reduced by 3,000 t (to 7,500 t) and the haddock quota by 1,900 t (to 2,200 t). The 1984 EC pollock quota was maintained at 6,000 t and the redfish quota increased 500 t, to 5,000 t. The Norwegian quota for herring caught west of Scotland was reduced by 500 t to 7,000 t in 1984. Quotas for North Sea herring were set in May, and of a preliminary 50,000 t TAC, Norway was allowed 15,000 t. Norway's mackerel quota west of Scotland was increased from 20,000 t in 1983 to 23,000 t in 1984. For the joint North Sea mackerel stock, Norway's quota was 24,500 t, the EC's 7,500 t. Norway's North Sea brisling quota was reduced from 40,000 t to 25,000 t at Norwegian request. Norway was also allotted a 2,450 t shrimp quota (2,500 t in 1983) off Greenland and a new 600 t quota in EC zones in the North Sea. Norway's dogfish quota was raised by 1,000 t, to 3,000 t.

Support Measures

The formal basis for Government subsidization of the Norwegian fishing industry is a 1964 agreement between the Ministry of Fisheries (MOF) and the Norwegian Fishermen's Union (NFU). The dual objectives of this agreement were to increase the fishermen's income to the level of other occupations and to lead eventually to a fishing industry independent of Government subsidies.

During the two decades of the agreement, the first objective appears to have been met. However, until 1982, annual subsidy negotiations normally resulted in agreements between the MOF and the NFU. For 1983 and 1984, the differences in the subsidies demanded by the NFU and offered by the Government were too large to be bridged through negotiations. In the absence of agreements, the MOF stipulated aggregate subsidies at NK1.1 billion for 1983, or 27 percent of the ex-vessel value of the Norwegian catch. An analysis of the 1983 subsidies shows that the product price supports and cost-reducing disbursements accounted for NK974 million, or nearly 90 percent of total subsidies. Measures aimed at making the fishing industry less dependent on state support were postponed, with NK115 million allotted for "efficiency and structural" measures.

In addition, the stockfish industry was granted NK200 million in liquidity loans and NK240 million State guarantees for stockfish exports to Nigeria. The opening demand and offer in the negotiations concerning 1984 fishery subsidies were NK2,033 million and NK600 million, respectively. The NFU reduced its demand to NK1,450 and the MOF raised its offer to NK1,100 and NK300 million in export guarantees, but the parties still could not reach an agreement.

Following a short "protest strike" by fishermen, the final government offer was presented to the Storting (Parliament) as a proposal and was adopted by the Storting on 16 December 1983.

In its Storting proposal, the MOF stressed the necessity of channeling Government support, to the greatest possible extent, into measures promoting more efficient and economic fishing operations, aimed at reducing future requirements for Government aid. The possibility of realizing this objective is hampered by two political considerations: 1) The fishing industry's importance for maintaining

employment and population levels in the coastal districts and 2) securing sufficient income for those employed in the fishing industry.

Due to continued fishing fleet and processing industry overcapacity, the MOF claims that NK200 million is needed for effort and processing capacity reduction (scuttling vessels or selling them for nonfishing purposes, closing down fish processing plants, and modernizing vessels and fish processing plants). An additional NK85 million was available for such purposes from previous years.

Special 1983 Government guarantees for stockfish exports to Nigeria were fully utilized by the end of the year. In October 1983, the Guarantee Institute for Export Credits (GIEK) stopped issuing guarantees for exports to Norway's major klippfish markets (Brazil and the West Indies) because of the weak and uncertain economic conditions in those countries. This set the stage for the NK300 million export guarantee arrangement for 1984. Such guarantees are primarily supposed to cover political risk, but can also cover part of the commercial risk.

Outlook

The short-term outlook for the two major Norwegian fish species is less promising than in many years. Arctic cod and capelin quotas for 1984 were drastically reduced during Soviet-Norwegian fishery negotiations to make up for years of overfishing. It is likely that this will mean further reductions in the number of vessels (many of which have been unable to fish enough during recent years to service the capital invested), and an increase in the already high unemployment among fisherman and fish processing workers, particularly in northern Norway.

In the longer run—toward the end of the 1980's—ocean biologists hold out the prospect of larger stocks of herring and cod owing to conservation efforts and successful spawning seasons in recent years. The establishment of a 200-mile economic zone, and a gradual reduction of foreign nations' fishing rights in this zone, should help secure more fishery resources for the Norwegian fishing fleet.

In addition, fish farming will help Norway maintain a position among the major fishing nations of the world. The abundance of protected areas along Norway's coast and favorable sea temperatures offer considerable opportunities for fish farming. Marine ranching of salmon and trout is expected to reach 50,000 t in the next few years, and the culturing of flatfish, cod, and lobster has also been initiated. (Source: IFR-84/33).

Norway Sets Shrimp and Capelin Records in 1983

Last year, 1983, was a very good year in general for Norwegian fisheries with increases in both quantity and first-hand value, the Norwegian Information service reports. Norwegian fishermen caught almost 300,000 tons more fish than they caught in 1982, reaching an aggregate catch of 2.9 million tons with a first-hand value of US$525.6 million.

Last year was also a record year for the Norwegian capelin and shrimp harvests. Capelin catches increased by over 300,000 tons to almost 1,500,000 tons, according to Fisheries Directorate data. The first-hand value of the record capelin catches alone increased by US$25.6 million. The first-hand value of harvested shrimp went up from US$53.3 million in 1982 to US$82.6 million in 1983 as the shrimp catch increased from 51,000 tons to 75,000 tons.

Cod Drops

In addition, the value of Norway's herring catches (including capelin catches) was expected to surpass US$166.6 million in 1983. However, cod catches declined and first-hand value fell from US$294.8 million in 1982 to US$243.5 million in 1983. Despite the reduction, the cod fisheries remained Norway's most important fisheries, calculated in NOK value, according to the Fisheries Directorate.

The first hand value of Norwegian sealing fell from US$1.6 million in 1982 to US$306,000 in 1983, according to the Shipowners' Association of North Norway, as the total catch decreased from 68,262 animals to 21,493. Less than half of the 1983 quota of 48,700 animals was caught. The low value of the catch was reportedly a result of difficult market conditions. Nevertheless, the shipowner companies believed that sealing should continue, not least out of consideration to the ecology.

Export Record

Norwegian exporters of fresh fish broke all records in 1983, reporting fresh and frozen fish sales worth US$294 million. This was US$102 million more than in 1982, according to Norinform data from the fish exporters association.

Reasons for the increases lay in the shrimp fisheries and the increased production and demand for Atlantic salmon. But even the earnings from salmon exports took second place to those from the shrimp fisheries. Last year 24,000 tons of shrimp were exported as against 18,000 tons in 1982, which was also reckoned to be a good year. The export value was US$134 million compared with US$75 million in 1982. An aggregate 75,000 t of shrimp were landed.

Traditional fish exports such as cod and saithe, however, had a relatively bad year. Norwegian exporters reportedly were impeded by EEC duties which make it difficult to sell these products in Europe.

Octopus Sales

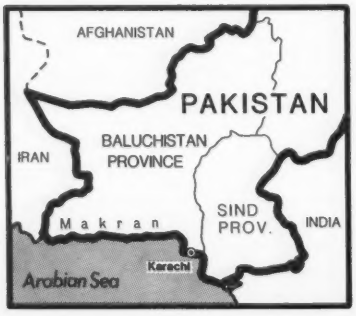
The total fisheries export figures included capelin, round-frozen mackerel, greenland halibut, and "akkar" (octopus) which is fast becoming a popular product. About 7,000 tons of akkar were exported last year, and export for consumption is also increasing (formerly it was mainly used as bait). Last year 15 countries purchased akkar from Norway for consumption. If the drift of akkar into the Norwegian fjords continues this year it could be a very interesting product in 1984, according to Norwegian authorities. Salmon production was also expected to increase by 40 percent in 1984 (over 1983).

Pakistan Set to Develop Deep-Sea Fish Reserves

Pakistan's new deep-sea fishing policy is aimed at promoting joint ventures with foreign countries, allowing Pakistan to fish previously underutilized offshore resources. Until 1982, almost all Pakistani marine fishing was done within 15 miles of the coast. Pakistani fishermen used artisanal fishing vessels and gear in shallow coastal waters less than 50 m deep.

Fishermen complained to the Pakistani Government about the depletion of fishery stocks and the increasing level of fishing by foreign vessels. In response to these complaints and because there was interest expressed by foreign governments in obtaining licenses to fish in Pakistani waters, the Pakistani Government became more active in promoting the development of the country's deep-sea fisheries. The availability of U.N. technical assistance and the example of India's efforts to utilize tuna resources also were factors influencing the Pakistani Government's decision.

The major impetus for Pakistan's new offshore fishing policy was a 1982 study of its fishery resources by the Food and Agricultural Organization (FAO) of the United Nations. The report concluded that as many as 17 deep-sea trawlers could be deployed in waters off Sind Province in the Arabian Sea (see map). The report recommended that deep-sea fishing ventures be restricted to waters beyond 35 miles of the coast to minimize competition with Pakistani artisanal fishermen.



On the basis of the FAO report, the Pakistani Government decided to actively participate in developing the country's deep-sea fishery. In 1982 and 1983, the Pakistani Government approved joint ventures between private Pakistani fishing companies and companies from North Korea, Singapore, and South Korea. In addition, the Asian Development Bank, the U.N. Development Program, and the European Economic Community provided assistance for a multidonor marine fisheries development project.

No official information on the terms of the joint ventures, or on their results, has yet been made public. The Pakistani press, however, has reported some information, citing unidentified Pakistani Government sources. According to these reports, the three approved joint venture companies obtained licenses for 14 foreign trawlers with another three trawlers that were expected to be authorized later. The number of trawlers deployed in Pakistani waters at any given time is unclear. Depending on the extent of the Pakistani equity in each joint venture, as much as 37 percent of the value of the catch is remitted to the Pakistani partners in foreign exchange; this sum includes a 10 percent royalty payment to the Pakistani Government. The total catch of the three joint ventures during the 18 months preceding March 1984 was 5,500 metric tons, and had an export value of $4.2 million. Of this total, the Pakistani Government received $419,000 as royalties. The main species landed were mackerel, ribbonfish, rock cod, squid, and cuttlefish.

The presence of foreign trawlers has raised strong opposition among local fishermen. The Karachi Fishing Boat and Trawler Owners Association has urged the Pakistani Goverment to suspend the operation of foreign-owned vessels which were claimed to be fishing in waters less than 35 miles from the coast. Fishermen cite the instances when the Pakistani Navy detected six foreign-owned trawlers fishing illegally 35 miles off the Makran coast (see map), an area from which their fishing licenses specifically excluded them. Also, three South Korean trawlers were seized in May 1984 for violating terms of their licenses and the owners paid fines to secure their release.

The chairman of the Pakistani Seafood Industries Association has also criticized the joint ventures. He argued that the Pakistani Government should concentrate on modernizing the fleet and gear of the traditional fishermen to better enable them to utilize the country's deep-sea fishery resources.

According to the NMFS Foreign Fisheries Analysis Branch, the Pakistani Government's position is complicated by its attempt to impose a new ban on coastal fishing of shrimp and lobster during June and July, as the FAO report had recommended. Artisanal fishermen, who depend largely on the coastal shrimp and lobster catch, claim that they are not overfishing, but that illegal fishing by foreign trawlers is affecting their catch and the decline of the resource. The Food and Agriculture Ministry, which includes the Marine Fisheries Department, is under pressure to review its deep-sea fishing policy and to increase surveillance of foreign trawlers. Inspection procedures have been tightened in recent months and catch reporting requirements strengthened.

Despite the criticism, local observers believe that it is unlikely that the Pakistani Government will be deterred from approving additional joint ventures. According to press accounts, at least two new joint venture proposals, providing for larger Pakistani equity in new joint venture companies than in those currently operating, are being reviewed. Moreover, Government-owned lending institutions are prepared to extend loans to the newly proposed joint venture companies while Pakistani fishing companies will acquire greater experience by drawing on the technical skills and market access derived from the foreign partners. Assuming Pakistani Government's approval, the joint venture agreements will lead to increased fishery catches and export earnings. (Source: IFR 84/53.)

EC, African Nations Expand Fisheries Ties

The European Community (EC) is attempting to alleviate some of the problems of its fishermen by expanding fisheries cooperation with African countries. The EC has already signed agreements with five West African nations (Senegal, Guinea-Bissau, Guinea-Conakry, Sao Tome and Principe, and Equatorial Guinea) (see map) and one East African island nation, the Seychelles in the Indian Ocean.

The agreements provide EC fishermen with increased access to fishing grounds claimed by African nations in exchange for fishing fees and fisheries assistance to those countries (Table 1). Some observers also note that EC-African relations will be significantly expanded once Spain and Portugal enter the European Community because both countries have extensive fisheries relations with many African countries.

Senegal

The EC signed its first fisheries agreement with an African country in June 1979 when a 2-year bilateral agreement with Senegal was concluded. The agreement has been periodically renewed, and the latest revision was signed in January 1984. The agreement's main provisions are:

1) The EC pays an annual $7.6 million compensation fee to Senegal's Treasurer-General and the State Secretariat for Senegalese Fisheries. Monetary figures in the EC-Senegal agreement are given in CFAF (Central French African Francs) and have been converted to dollars using the exchange rate of 405 CFAF per U.S. dollar, prevailing on 31 December 1983.

2) The EC contributes $247,000 to finance a Senegalese fisheries program carried out by the Oceanographic Center in Dakar.

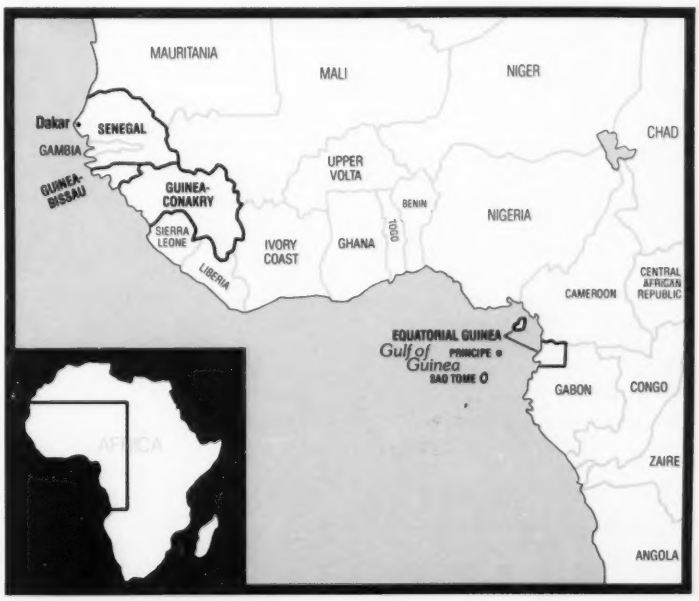
3) The EC provides 20 study and training grants for a 5-year period to allow Senegalese fishermen to study in specialized EC fishery schools.

4) EC tuna fishermen pay fees of about $6.00 per metric ton (t) of tuna caught by vessels which land their entire catch in Senegalese ports, and $18.00/t of tuna for vessels not landing their entire catch in Senegal. Other EC fishermen pay fees of $21 per gross registered tonnage (GRT) per year for vessels landing their entire catch in Senegal, and $42 per GRT per year for those vessels not landing their catch in Senegal. The higher fees for vessels not landing their catch in Senegal are designed to encourage EC fishermen to process their catch in

Table 1.—Terms of EC fisheries agreements with African countries.

Country	EC payments (US$1,000) Annual	EC payments (US$1,000) Other	Vessel fees (SUS/GRT/year)	Fishing fees (SUS/ton)	Max. fishing effort Capacity (Avg. GRT)	Max. fishing effort No. of vessels
Senegal	7,600	247	21	[1]18	[2]26,000 [3]14,000	
Guinea-Bissau	1,300	220	97	18	[2]7,500	[2]50
Guinea-Conakry	616	176	97	18	[3]3,000	[2]50
Equatorial Guinea	158			18		[2]27
Sao Tome	[4]158	35		18		[2]27
Seychelles	[4]265			18		[2]18

[1]Fee for freezer vessels not landing their catch in Senegal; vessels landing their catch in Senegal are charged $6.00/t of tuna.
[2]Applies only to tuna vessels.
[3]Applies only to bottom trawler and other nontuna vessels.
[4]For EC catches of tuna up to 4,000 t/year off Sao Tome and up to 6,000 t/year off Seychelles; EC payment increases proportionately if the catch exceeds 4,000 and 6,000 t, respectively.
Source: *Official Journal of the European Communities*, various numbers.



Senegal (and thus provide employment) rather than take their catch to Europe for processing.

5) Senegal issues licenses to EC vessels with a cumulative annual total of 40,000 GRT. Of this total, 23,000 GRT may consist of tuna freezer vessels which do not land their catch in Senegal, 3,000 GRT may be vessels which land their tuna catch in Senegal, and 14,000 GRT may be other non-tuna vessels.

Guinea-Bissau

The EC signed an agreement with Guinea-Bissau in February 1980 and renewed the agreement in a slightly modified form in March 1983 for an additional 3 years. The agreement allows EC fishermen in Guinean waters to deploy 25 freezer tuna vessels (with an average tonnage of 900 GRT each), 25 pole and line vessels (130 GRT average), and several bottom trawlers with an average annual tonnage of 7,500 gross registered tons. In return, the EC is to pay Guinea-Bissau an annual sum of $1.3 million, as well as a lump sum of $220,000 to finance a stock assessment study. EC fishermen pay fees of about $97 per vessel GRT per year and $17.60 per ton of fish caught.

Guinea-Conakry

The EC signed an agreement with Guinea-Conakry (the Revolutionary People's Republic of Guinea) in December 1982 for a 3-year period. The agreement is very similar to that signed with Guinea-Bissau and provides that the EC pay Guinea-Conakry $616,000 per year as well as a one-time sum of $176,000 to contribute towards a fishery resources program in that African nation. The fishing fees and allowable EC fishing effort are the same as those in the agreement with Guinea-Bissau, except that the average annual tonnage of trawlers is set at 3,000 GRT instead of 7,500 GRT.

The EC has provisionally approved three additional fishery agreements with West African countries, and EC fishermen have already begun fishing off the coasts of these nations according to the terms set out in the agreements.

Equatorial Guinea

In July 1983 the EC provisionally approved a 3-year fisheries agreement with Equatorial Guinea. The agreement allows 27 EC tuna fishing vessels to operate off the Guinean coast and requires their owners to pay $17.60 per GRT per year. In addition, the EC will contribute $158,000 per year to Equatorial Guinea for fisheries research activities. This contribution applies to annual EC tuna catches of up to 4,000 t. If the quantity of EC tuna catches exceeds 4,000 t, the EC contribution is to increase proportionately (i.e., if the EC tuna catch is 8,000 t, the contribution will be $316,000).

Sao Tome and Principe

In October 1983, the EC also provisionally approved a 3-year fisheries agreement with Sao Tome and Principe. The terms of the agreement are exactly the same as those set out in the EC-Equatorial Guinea agreement, except that the EC pays an additional one-time sum of $35,000 to the National Bank of Sao Tome and Principe.

Seychelles

The EC signed a 3-year fisheries agreement with the Seychelles on 18 January 1984 allowing 18 EC tuna freezer vessels to fish off the Seychelles in return for a fee of $18.50/t of tuna caught. The EC will also pay the Seychelles $265,000 a year for annual tuna catches of up to 6,000 t. Should the EC catch exceed 6,000 t, the EC contribution will increase proportionately.

D'Ormesson Report

A report prepared by European Parliament Member Oliver d'Ormesson recommends that the European Community use the expected entry of Spain and Portugal into the EC, tentatively scheduled for 1986, as a means of increasing the EC presence in Africa. Spain is the key nation in the report's recommendations because that country is one of the major nations fishing off both western and southern Africa.

Spain catches more fish by value than any foreign country operating off West Africa and holds second place, after the Soviet Union, in quantity (Table 2). The Spanish catch is greater in value because it is composed largely of such high-valued fishes as tuna, cephalopods, crustaceans, and hake while the Soviet catch is composed mostly of smaller low-value pelagic species. Spain has also concluded fishery agreements (including sales of vessels) with Morocco, Mauritania, Senegal, the Ivory Coast, Equatorial Guinea, Namibia, and Angola.

When, and if, Spain joins the EC, all of its external fishery relations like those of other EC members, will be conducted by the Community. In addition, all current Spanish agreements with third countries will be taken over by the EC upon their expiration. D'Ormesson sees this as an excellent opportunity for the EC to increase its influence in West Africa by entering into a greater number of agreements with more countries of the region.

D'Ormesson recommends that the European Community set up, as soon as possible, a conference between itself, Spain and Portugal, and West African coastal countries, to coor-

Table 2.—Eastern central Atlantic and southeast Atlantic catches by major distant-water fishing country, 1982, in thousands of metric tons.

Country	African area catch		
	Western[1]	Southern[2]	Total
U.S.S.R.	956	888	1,844
Spain	444	208	652
Romania	84	81	166
GDR	95	31	126
Poland		98	98
ROK	86		86
Japan	30	53	83
France	59		59
Bulgaria	7	50	57
Portugal	12	13	26
Other	42	12	55
Total	1,815	1,435	3,250

[1]FAO Area 34.
[2]FAO Area 47.
Source: FAO "Yearbook of Fishery Statistics, 1982".

dinate the fishery activities of all parties in the region. The first task of the conference would be to increase the degree of cooperation between the West African countries themselves in order to establish a unified policy for the management of fishery stocks, set fixed tariff schedules, and standardize license fees for foreign fishing vessels. The conference would also address the question of establishing a system of fisheries enforcement to reduce the number of infractions against conservation regulations, currently a serious problem in the region.

D'Ormesson sees a number of benefits to the EC as a result of a coordinated West African policy. First, the presence of the Soviet Union and its allies in the region could be partially balanced by an increased EC role in West African fishery affairs. The Soviet Union is the major foreign fishing nation in the region in terms of quantity of catch, while Romania, the German Democratic Republic, and Poland rank third, fourth, and fifth, respectively (Table 1). These countries have also concluded a number of fishery agreements with West African nations.

The EC, on the other hand, harvests a relatively limited catch in the region, and only France ranks among the top ten foreign fishing nations there by quantity of catch. With the addition of Spain and Portugal, however, the EC would comprise the region's second largest foreign fishing group by volume and the most important by value. D'Ormesson anticipates that the increased EC participation in the region could act to balance the presence and influence of Soviet bloc countries.

Economically, the EC would stand to gain much from increasing its presence in West Africa. The EC members, especially in the Mediterranean, are facing greatly depleted fishery resources, and are eager to add to their available fishing opportunities. Furthermore, many countries, particularly France, have expressed their fears over the possible adverse consequences to their fishing industries when and if Spain and Portugal join the EC. Spain has one of the largest fishing fleets in the world and the French are worried that the Spanish will try to gain access to the fisheries jurisdiction of current EC members once Spain joins the Community. An increase in the Community's fishing effort in West Africa would also increase the EC's available fishery resources. It would also enable the EC to direct the Spanish fleet away from the Community's present fisheries jurisdiction.

Finally, d'Ormesson notes that the West African countries will benefit from increased EC involvement in regional fisheries. The development of these fisheries can play a large part in aiding the EC efforts, under the Lome Agreements, to improve food supplies available to the African peoples. The report points out that annual per capita foodstuff production in Africa has been declining during the past two decades and that fisheries present a relatively underutilized means to increase the region's food supplies. (Source: IFR-84/29.)

Mexico Encourages Rock Shrimp Fishery

The Mexican Secretariat of Fisheries (SEPESCA) is encouraging cooperative fishermen to develop the Contoy shrimp fishery. Contoy Island is located off the coast of the States of Yucatan and Quintana Roo along the northeastern coast of the Yucatan Peninsula (see map). The shrimp fishery off Contoy is primarily for rock shrimp, *Sicyonia brevirostris*, which was conducted by U.S. fishermen until they were phased-out of the Mexican shrimp fishery in 1980. This fishery is much more difficult to conduct than that for other shrimp species because trawling on rocky bottoms often tears up trawls.

Mexican fishermen until recently have taken only small quantities of the species.

SEPESCA has held meetings with cooperatives on the rock shrimp fishery. Cooperative leaders, throughout The Federation de Cooperativas Pesqueras de Quintana Roo, have expressed an interest in developing the fishery. Following the meetings between SEPESCA and the cooperative leaders, the Banco Nacional Pesquero y Portuario (BANPESCA) agreed to transfer 50 shrimp trawlers to three cooperatives in Quintana Roo. The transferred trawlers had been repossessed by BANPESCA from other cooperatives which were not meeting mortgage payments.

The three cooperatives in Quintana Roo operated only 25 shrimp trawlers as of December 1983. The cooperatives have an additional seven trawlers, but four were in such poor condition that they are not serviceable. The other three trawlers are new, but BANPESCA had not yet provided credits needed to purchase trawl nets and other gear.

The 50 additional trawlers will increase the cooperative shrimp fleet in the state to 75. If the needed credits are provided by BANPESCA to repair old and equip the new vessels, as many as 80 trawlers may be deployed off Contoy and Quintana Roo by the end of 1984. Some observers point out, however, that

based on previous experiences, some of the transferred trawlers may be in poor condition and need overhauling before they can be used in the fishery.

Mexican press reports mention that one reason for SEPESCA's desire to develop the Contoy fishery is the fact that U.S. fishermen once fished there and continue to be interested in the fishery. One Mexican source reports that U.S. fishermen contacted Mexican officials in 1983 concerning U.S. access to the Contoy grounds. The Mexican press also reports that the Mexican Navy has intensified patrols off Contoy to prevent any foreign fishing. (Source: IFR-84/26.)

Mexico Starts New Gulf Longline Fishery

Mexico has initiated a longline tuna fishery in the Gulf of Mexico. The fishery is being conducted by Productos Pesqueros de Alvarado (PPA), an affiliate of the giant, state-owned fishing company Productos Pesqueros Mexicanos (PPM). PPA officials report that their vessels, operating from the Alvarado fishing port near Veracruz[1] would land about 900 metric tons (t) of tuna and other species in 1983. The NMFS Branch of Foreign Fisheries Analysis believes there is a substantial incidental billfish catch, but no statistical data is available on the quantities involved.

The new Mexican fishery was pioneered by a Captain Izumi, a Mexican citizen of Japanese ancestry, who for years tried to convince government officials, cooperative members, and private fishermen to initate a tuna longline fishery, but with little success. The longline techniques that Izumi recommended were new to Mexican fishermen who hesitated to enter an unfamiliar, new fishery.

PPM finally decided, as a result of Izumi's recommendations, to begin test fishing in 1982. This exploratory fishing was conducted by PPA which attracted fishermen by outfitting a boat, guaranteeing a minimum salary, and promising to purchase the catch at 7.50 pesos[2] per kilogram. The PPA campaign began in July 1982 and the results proved so promising that the fishermen themselves asked to participate in future fishing trips. The fishermen asked that their compensation be changed from a minimum salary to a flat purchase arrangement of 30 pesos per kilogram. The fishermen only landed 90 t, but the results were promising enough for PPA to plan commercial operations in 1983.

PPA's 1983 longline operations began in May and continued into the fall. The company deployed two old Dutch-built trawlers (26 m long) especially rigged for longlining; the *Tiburon V*, a new Japanese-built longliner[3] (44 m long); and several U.S.-built fiberglass boats (14.6 m long)[4] The Dutch trawlers reported catches of 30 t in 2-week trips[5]. The *Tiburon V* reported catches of 160 t by mid-July. The small fiberglass boats reported catches of over 10 t each in 6- to 8-day trips.

PPA was reportedly paying the fishermen 50 pesos per kilo for tuna and shark near the end of the fishing period (probably for billfish, also, although actual confirmation was not available). PPA covered the costs of maintaining and repairing the vessels, supplying them, and paying off the remaining mortgage, if any. The fishermen reported substantial earnings of more than 200,000 pesos per month. Some fishermen complained, however, that they had to sometimes spend unnecessarily long periods in port at Alvarado, primarily because of an ice shortage. PPA officials were especially pleased, not only at the excellent catch rates, but because much of the yellowfin tuna catch was the more easily marketed larger fish, averaging 40 kg. PPA had also requested that PPM provide five additional longliners, which would enable the company to substantially increase its fishing effort. (Source: IFR-83/113).

Poland Transfers Fishing Efforts to South America

The Polish fishing industry was adversely affected when the United States denied it access to U.S. fishing grounds after the 1981 declaration of martial law in Poland. The U.S. 1981 catch allocation to Poland was 230,000 tons. Poland only partially succeeded in finding alternative fishing grounds and, as a result, the Polish 1982 fisheries catch was only 582,000 t, an 8 percent decline from the 630,000 t taken in 1981.

Many trawlers displaced from U.S. waters were deployed in high-seas fisheries off Peru, Chile, and Argentina. Complete catch statistics for 1983 were not yet available, but the Poles claim to have developed new high-seas fishing methods and will probably report improved results in 1983. Polish Government officials claim that their squid catch alone off Argentina exceeded 100,000 t in 1982 and that squid has become a major export commodity.

While improved fishing methods

[1] Alvarado was the first commercial fishing port built by Mexico and is still the most important Gulf port for Mexican finfish fisheries. About 60 medium and large vessels are currently based there.

[2] The Mexican peso has fluctuated widely on international markets since January 1982. The free market rate was about 150 pesos to the U.S. dollar late last year.

[3] The *Tiburon V* is one of a series of 10 longliners built in Japan. Most of the other vessels are currently deployed in shark longlining in the Pacific.

[4] These vessels were originally built primarily for snapper fishing. Additional information on the fiberglass boats can be obtained by requesting "Mexico. U.S. Built Fishing Boats Prove Successful" (IFR-83/108) from your local NMFS Statistics and Market News Office.

[5] Nine actual fishing days.

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA. Terminal Island, CA 90731, or the International Fishery Releases (IFR), Language Services Biweekly (LSB) reports, or Language Services News Briefs (LSNB) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington DC 20235.

may have helped in 1983, the Poles also benefited from the British 150-mile Exclusion Zone around the Falkland Islands which had prevented the Argentines from fully enforcing their 200-mile zone. Polish officials say that they have also developed new processing techniques for both squid and krill which, combined with administrative reforms, should help make 1984 another succesful year for Polish fisheries off South America.

Ecuador Tries New Shrimp Export Rules

The Ecuadorean Government implemented new shrimp export regulations on 23 January 1984 making exports of small shrimp, selling below a new minimum export price, impossible. The regulations were sharply criticized by the country's fishing industry and caused a massive backlog of shrimp in Ecuadorean ports. One press report indicated that, after a week, nearly 700 metric tons (t) of shrimp worth $3.5 million was being held in Ecuadorean ports. Finally, on 30 January Minister of Natural Resources, Gustavo Galindo, suspended the regulations, allowing exports to resume. The Government and the industry then attempted to develop more workable export regulations.

The Government's initial decree established a minimum reference price for shrimp exports at $4.50 per pound, thus eliminating exports of smaller shrimp. Ecuadorean shrimp is sorted into 17 different sizes. Most of Ecuador's shrimp are of the smaller size produced by shrimp farmers in the booming shrimp culture industry. Pond operators believe that they can maximize profits by producing primarily the smaller shrimp.

As a result, pond operators found that, after 23 January they could only export 6 of the 17 sizes. The new Government regulations were an effort to combat the common practice of "under-invoicing" exports, whereby an exporter reports to the Government an export price lower than the true one, and then either keeps the profits in a U.S. bank account, or sells the dollars in Ecuador at the free market rate of 90 sucres to the dollar. The Government only gives shrimp exporters 60 sucres for each dollar remitted through the Central Bank.

The Government would like pond operators to diversify production and raise more of the larger shrimp. The larger sizes (21/25 shrimp per pound and down) command higher market prices of from $5.30 to over $8.00. Government officials claim that if shrimp farmers would concentrate on producing the larger sizes, greater revenue for the country would eventually result.

By rearing the shrimp longer, shrimp farmers would harvest their ponds only three times per year, instead of the current average of six times per year. Government officials maintain that less frequent harvests would also be ecologically beneficial because they would not exhaust the supplies of "seed" (post-larvae) that are currently collected in the estuaries to stock the ponds. Shrimp fishermen and some Government biologists are concerned about the extensive harvest of post-larvae in the estuaries.

Shrimp exporters, on the other hand, were sharply critical of the new regulations. They claimed that the smaller shrimp (above 21/25 shrimp per pound) accounted for 85 percent of exports. In 1983, shrimp was Ecuador's second most important export, after petroleum, constituting 8 percent of all exports, and earning approximately $180 million.

The large shrimp (21/25 per pound and down) are mostly caught at sea, and industry spokesman like Agronomist Hugh Alban Nugues of the Federacion Ecuatoriana de Exportadores de Camaron, charged that only 4 of the 58 companies currently exporting shrimp have the capacity to fish for shrimp in the open sea. The 28 January regulations would thus have resulted in an export monopoly for a small number of companies.

The shrimp farmers also complained that if they were required to keep their shrimp in ponds for longer periods (three harvests per year instead of an average six), higher feed costs, equipment needs, and increased maintenance costs would make it unprofitable for them to stay in business. Some were also concerned about the greater "risks" associated with culturing shrimp for longer periods and using feed.

They also stated that requiring them to sell 85 percent of the country's number two export product domestically, at local prices, was a ridiculous way to deal with the underinvoicing problem. (An Ecuadorean Government decree issued in October 1983 had reduced the amount of shrimp which had to be sold locally to only 2.7 percent of domestic production.) The culturists also pointed out that the regulations could affect the jobs of over 300,000 Ecuadorean workers who are directly or indirectly involved in the industry. (Source: IFR-84/23).

Japan Reduces Tariffs on Three Fish Products

Japan has announced the reduction of import tariffs on three fishery products, effective 1 April 1984. Import tariffs on salted salmon dropped from 15 percent to 12 percent, those on salted salmon roe from 5.9 to 5 percent, and those on fresh, chilled and frozen crab from 7.5 to 6 percent.

Mexico Sets Campaign to Protect Sea Turtles

The Mexican Government has initiated a new program to protect turtles in the Caribbean coastal state of Quintana Roo. Restaurants have been prohibited from including turtle meat and eggs on their menus. Turtles protection centers are scheduled to be established at Cabo Catoche,Contoy, and Isla Mujeres to hatch eggs and raise the hatchlings.

New NMFS Scientific Reports Published

Some publications listed below may be sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Copies of all are sold by the National Technical Information Service, Springfield, VA 22151. Writing to either agency prior to ordering is advisable to determine availability and price (prices may change and prepayment is required).

NOAA Technical Report NMFS SSRF-776. Richards, William J. **"Kinds and abundances of fish larvae in the Caribbean Sea and adjacent areas."** May 1984, 54 p.

ABSTRACT

Fish larvae were studied from collections made in the western central Atlantic, principally the Caribbean Sea. Larvae were collected with bongo and neuston nets during two cruises of the FRV *Oregon II* in the summer of 1972 and winter of 1973. Eighty-eight families were represented in the bongo collections, and 58 families were represented in the neuston collections, for a total of 97 families represented overall. In the bongo tows, myctophid larvae were the most abundant and were represented in every collection. Gonostomatid larvae ranked second in abundance and occurred in all but two collections. Other abundant larvae were bothids, scarids, bregmacerotids, paralepidids, gobiids, scombrids, labrids, carangids, and serranids. The top 15 families accounted for 69-74 percent of the total larvae for both cruises.

On the summer cruise, five stations had >1,000 larvae under 10 m² of sea surface, with two of these near the Virgin Islands, one east of the Antilles, one south of Hispaniola, and one between Cuba and the Bahama Islands. On the winter cruise, two stations had 1,000 larvae under 10 m² of sea surface, and these were off the northern coast of Venezuela in an area of upwelling. This area is especially abundant in reef fishes with mid-depth fishes also common. Large concentrations of clupeids are not seen here, since they are in the Gulf of Mexico for lack of a large shelf area. Oceanic pelagic fishes, such as the scombrids, were only moderately abundant here compared with the eastern Atlantic. Since there is no major nutrient transport to most of the area, great abudances of fish are precluded. For the most part, the area is uniform in distribution and abundance of larvae, the exception being the northern coast of South America, an area of upwelling.

NOAA Technical Report NMFS SSRF-782. Wenner, E. L., W. P. Coon III, M. H. Shealy, Jr., and P. A. Sandifer. **"A five-year study of seasonal distribution and abundance of fishes and decapod crustaceans in the Cooper River and Charleston Harbor, S.C., prior to diversion."** July 1984, 16 p.

ABSTRACT

Fluctuations in the distribution and abundance of fishes and decapod crustaceans collected by a 6 m otter trawl net

ZEOLITES AND FISH CULTURE

"Zeo-Agriculture: Use of Natural Zeolites in Agriculture and Aquaculture," edited by Wilson G. Pond and Frederick A. Mumpton, has been published by Westview Press, 5500 Central Avenue, Boulder, CO 80301, as one of the Westview Special Studies in Agriculture/Aquaculture Science and Policy series. Pond is a research leader in nutrition at the USDA Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Neb.; Mumpton is a professor in the Department of the Earth Sciences, State University of New York, College at Brockport. The volume is a collection of research and review papers presented by an international group of experts at the "Zeo-Agriculture '82" conference organized by Mumpton.

Zeolites are a group of natural, inorganic silicates. Discovered in 1756, nearly 50 species of natural zeolites have now been recognized; more than 100 others have been synthesized in the laboratory. They are crystalline, hydrated metal aluminosilicates of alkali and alkaline earth cations with infinitely extending three-dimensional networks of AlO_4 and SiO_4 tetrahedra linked by the sharing of all oxygen atoms. As such, they are characterized by an ability to lose and gain water reversibly and to exchange some of their constituent cations without major change in structure. With their natural ion-exchange, absorption, and hydration properties, these minerals have broad applications for agricultural and aquacultural sciences: They can act as slow-release fertilizers for nitrogen and potassium, carriers for herbicides and pesticides, traps for heavy metals in sewage-sludge amended soils, and decaking agents for feed and fertilizer storage. They can remove toxic ammonia from fish hatchery waters and provide oxygen-enriched air to aquacultural systems.

Though some zeolite studies have shown great agricultural promise, others have not. However, their beneficial effects in fish hatchery/culture systems seem clearer, allowing reductions in energy use and increasing production. Additionally, use of zeolites in certain solar refrigeration systems may benefit fishery product storage in some areas. Some also forsee potential improvement in fish food with zeolites.

Mumpton begins with an overview of the use of natural zeolites in agriculture and aquaculture. The following section, "Fundamentals of Zeolite Science," reviews their occurrence, availability, properties, etc., and provides background information on this emerging field.

Sections 3, 4, and 6 review studies and research the uses of natural zeolites in agronomy and horticulture and in animal science and nutrition, and their use in agricultural engineering (animal wastes treatment, soil treatment, solar refrigeration). The

from the Cooper River-Charleston Harbor estarine system (South Carolina, USA) were examined over a 5-year sampling period. A total of 101 fish species and 41 decapod crustacean species were collected. Species richness was greatest at stations nearest the harbor mouth. Annual fluctuations in species abundance were apparently related to low bottom-water temperatures which affected year-class strength. Ten species accounted for ~90 percent of the total number and ~71 percent of the total biomass of finfishes collected in the estuary; *Stellifer lanceolatus, Anchoa mitchilli, Micropogonias undulatus, Brevoortia tyrannus, Leiostomus xanthurus, Symphurus plagiusa, Bairdiella chrysoura, Cynoscion regalis, Urophycis regia* and *Trinectes maculatus.* The decapod crustaceans *Penaeus setiferus, P. aztecus, Xiphopenaeus kroyeri,* and *Callinectes sapidus* dominated the finfishes in abundance but not biomass. They composed ~96 percent by number and ~97 percent by weight of the total decapod fauna. The biomass of fishes from this study is lower than values reported for other estuaries along the Atlantic coast of the United States.

The Cooper River-Charleston Harbor estuarine system, an important nursery area for fishes and decapod crustaceans, is characterized by gradual changes in faunal assemblages and considerable overlap in spatial distributional patterns of resident and transient species. Numerically dominant species of fish and decapod crustaceans form assemblages which are spatially and temporally ubiquitous. Resident estuarine species and stenohaline marine species are more restricted in their distribution.

NOAA Technical Report NMFS SSRF-783. Maurer, Don, and Roland L. Wigley, **"Biomass and density of macrobenthic invertebrates on the U.S. continental shelf off Martha's Vineyard, Mass., in relation to environmental factors."** July 1984, 20 p.

ABSTRACT

The mean density and mean biomass of macrobenthic invertebrates on the U.S. continental shelf off Martha's Vineyard, Mass., were 3,008/m² and 245.7 g/m², respectively. The latter estimate was considerably higher than values from the North Sea, Scotian Shelf, and Middle-Atlantic Bight. Mollusks (pelecypods and gastropods) and echinoderms (echinoids and ophiuroids) greatly influenced patterns of total biomass distribution. The ocean quahog, *Arctica islandica,* was the dominant species in terms of biomass. Total density was dominated by crustaceans (amphipods), polychaetous annelids, mollusks (small pelecypods), and echinoderms (ophiuroids). Mean density of molluscans was positively associated with sediment size. Mean biomass and density of crustaceans were negatively associated with depth, grain size, and bottom temperature, whereas the same parameters for the Echinodermata were positively associated with those environmental factors.

Three faunal assemblages emerged which were analagous to those described from earlier studies on Georges Bank (sand fauna, silt-sand fauna, muddy-basin fauna). The fauna from the Mud Patch most closely resembled the silty-sand fauna.

NOAA Technical Report NMFS 6. Collins, L. Alan, and John H. Finucane. **"Ichthyoplankton survey of the estuarine and inshore waters of the Florida Everglades, May 1971 to February 1972."** July 1984, 75 p.

ABSTRACT

Quarterly ichthyoplankton sampling was conducted at 16 estuarine and 24 inshore stations along the Florida Everglades from May 1971 to February 1972. The area is one of the most pristine along the Florida coast. The survey provided the first comprehensive information on seasonal occurrence, abundance (under 10 m² of surface area), and distribution of fish eggs and larvae in this area. A total of

---

fifth section relates the use of clinoptilolite for ammonia removal in fish culture systems and in salmon rearing. And, several Italian scientists evaluate Phillipsite tuff for ammonia removal and its use in ammonium ion exchange in aquaculture systems. The conference presented much useful information for those unaware of current studies of zeolite research, its present uses, and its potential. Indexed, the 296-page hardbound volume is available from the publisher for $52.50.

Principles of Sonar Systems for Fisheries

Publication of **"Fisheries Sonar"** by R. B. Mitson has been announced by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. The new volume incorporates and greatly updates D. G. Tucker's 1966 volume "Underwater Observation Using Sonar." Mitson is with the Lowestoft Fisheries Laboratory of England's Ministry of Agriculture, Fisheries, and Food.

The book begins with an introduction to several methods of obtaining information under water for fish harvesting, fisheries research, oceanography, navigation, etc. Chapter 2 then provides basic technical data on acoustic waves, how they behave, and how beams and echos are formed. Chapter 3 reviews basic principles of simple sonar systems, with numerous figures of schematic drawings and photographs of echo-sounder recordings and CRT displays. The author also discusses transducers, theoretical considerations of sonar systems, noise, calibration, etc.

Processing of sonar signals from fish is discussed in chapter 4, while chapter 5 reviews the limitations and use of fishing echosounders, including use in demersal fish detection, pelagic fishing, and CRT displays in echosounding. Chapter 6 discusses horizontal beam sonars and their fisheries applications (practical sonar systems, operating and interpreting sonar, electronic beam scanning, computer controlled display, and color sonar). Finally, chapter 7 provides a look at other types of sonar (sonar imaging systems, frequency modulated sonar, long-range sonar and sector scanning sonar), acoustic estimation of fish abundance, freshwater vs. marine sonar requirements, detection of deep-water fish, and a look at future trends.

The author emphasizes practical interpretation and has provided a good clear review of basic physics of acoustics and the principles and operation of sonar systems. The volume is well illustrated with 140 diagrams and photographs, and includes a section on paper recordings and color displays of fish traces. The 287-page hardbound volume has a subject index and a glossary, and is available from the publisher for £26.00.

209,462 fish eggs and 78,865 larvae was collected. Eggs, were identified only as fish eggs, but among the larvae, 37 families, 47 genera, and 37 species were identified. Abundance of eggs and larvae, and diversity of larvae, were greatest in the inshore zone. The 10 most abundant fish families which together made up 90.7 percent of all larvae from the study area were, in descending order of abundance: Clupeidae, Engraulidae, Gobiidae, Sciaenidae, Carangidae, Pomadasyidae, Cynoglossidae, Gerreidae, Triglidae, and Soleidae. Clupeidae, Engraulidae, and Gobiidae made up 59.9 percent of all larvae. The inshore zone (to a depth of about 10 m) was a spawning ground and nursery for many fishes important to fisheries. The catch of small larvae (≤ 3.5 mm SL) indicated that most fishes identified from the 10 most abundant families spawned throughout the inshore zone at depths of ≥ 10 m, but *Orthopristis chrysoptera*, Gerreidae, and *Prionotus* spp. spawned at depths of > 10 m, with offshore to inshore (eastward) larval transport. Salinity was one of several environmental factors that probably limited the numbers of eggs and larvae in the estuarine zone. Abundance of eggs and larvae at inshore stations was usually as great as, and sometimes greater than, the abundance of eggs and larvae at offshore stations (due west of the Everglades).

Fish Populations and Their Analysis

"Fish Stock Assessment," subtitled "A Manual of Basic Methods" and written by J. A. Gulland, has been published as Volume 1 in a new FAO/Wiley Series on Food and Agriculture by John Wiley & Sons, Inc., One Wiley Drive, Somerset, NJ 08873. Gulland is Chief of the Marine Resources Service of the FAO Fishery Resources and Environment Division in Rome.

The author opens with an introductory chapter explaining why fish stock assessment is needed, the models used, and the effects of fishing on a population. The bulk of the book then deals with basic single species analyses. Chapters discuss the main types of fishery data obtained and used, methods of analysis, and methods of estimating such parameters as growth, mortality, etc. Two basic types of models are described—the simple surplus-production approaches and the analytic, age-structured models. Later chapters discuss methods used to account for other factors that affect stocks of individual species and interactions between different species.

The volume is a very good, practical handbook, providing many selected and additional references, as well as question and answer exercises for each chapter. The author outlines the theoretical basis of the methods described, as well as the limitations of the various techniques. An Appendix provides tables of yield per recruit for selected value of M/K. As a review and description of the techniques used in assessing fish stocks, evaluating the effects of fishing on them, and gauging the likely impact of different policies for developing and managing fisheries, the book is a handy and concise reference. Indexed, the 223-page hardbound volume is available from the publisher for $34.95.

The Management of Marine Fisheries

"Fisheries Management: Theoretical Developments and Contemporary Applications" by Geoffrey Waugh has been published as a Westview Replica Edition by the Westview Press, 5500 Central Avenue, Boulder, CO 80301. Waugh is a senior lecturer in economics at the University of New South Wales, Australia, and a fisheries management consultant to the NSW government. The Replica Edition series is designed to permit rapid publication of original scholarly works (softcover, typescript) in very small printings at high standards.

The book contains three parts: Part One reviews the problem of excessive depletion and the types of models that can be utilized to manage fishery resources. The author uses three fisheries for illustration: The international whale fishery, the Pacific halibut fishery, and the Western Australian rock lobster fishery.

Part Two is concerned with the practical problems of management. Fishery program objectives are evaluated and the types of regulations of fishing activity and catch level are evaluated "in terms of economic efficiency, flexibility and ease of implementation and enforcement."

Part Three examines the application and development of fishery management tools in Australia's Exmouth Gulf prawn fishery and the New South Wales abalone fishery. In sum, the author reviews the development of fisheries theory, outlines and develops bioeconomic models that can be applied to fisheries, and discusses institutional and regulatory possibilities for successful fisheries management, utilizing two examples of Australian fisheries. Paperbound and indexed, the 247-page volume is available from the publisher for $21.50.

IGFA Lists World Record Game Fishes

The 1984 edition of **"World Record Game Fishes,"** Elwood K. Harry, Director, published by the International Game Fish Association, is much more than a listing of the largest sport-caught and fly-caught freshwater and saltwater fishes. Although the angling records are a significant part, the book also presents articles and data of interest to sportsmen, conservationists, and other professionals involved in marine recreational fisheries.

Standard annual sections relate IGFA's philosophy, goals, etc., its international angling rules, world record requirements, and fishing contest and club requirements, as well as a guide to the identification of more than 150 major game fish species. Appendices list fish record-keeping organizations worldwide, U.S. state record-keeping agencies, and illustrate fishing knot tying techniques. Also provided is an index to common and

scientific names of fishes.

New articles this year include "A scientific look at light line fishing," by Paul C. Johnson, for those seeking the best chance of setting angling records with ultralight tackle. Well-known angler Stu Apte gives expert advice on catching world record fish and flies, while another prominent angler, Peter Goadby, discusses Sport fishing for sharks—the when, where, and how.

And, NMFS fisheries scientists Edwin L. Scott and Grant L. Beardsley of the Southeast Fisheries Center provide a worldwide inventory of marine and anadromous fish tag and release programs. Included is data on the history and uses of fish tags and tagging, as well as an extensive listing of state, federal, and international fish tagging programs, including species tagged and number tagged, area of tagging operations, type of tags used, tagging cooperators, and the chief scientist involved. Finally, "Fishing rods and their classification" is related by Joy Dunlap.

With 619 new world game fish records in 1983, the records section has been vastly updated. It includes listings (as of 1 January 1984) for IGFA freshwater and saltwater all tackle records (up to 130-pound test line), line class world records, and fly rod world records. Species are listed alphabetically by common names. IGFA also reports ample opportunities for record-seeking anglers, especially since expanding its all-tackle record program to species not previously listed.

A revised and expanded Glossary is keyed to the section on "Species Identification." Also included is a "Multilingual Guide to Common Names of Saltwater Fishes" in such languages as French, German, Hawaiian, Italian, Japanese, Portuguese, and Spanish.

1984 also marks the 45th Anniversary of IGFA's service to anglers. The organization, founded in 1939, is the largest data collection center for recreational angling in the world. Its extensive International Library of Fishes catalogs both popular and scientific literature from around the world on species, angling, biology, etc., and acts as an international clearinghouse for such data.

In sum, the paperbound volume is the comprehensive listing of world angling records and fish tagging programs, with an excellent selection of articles of interest to conservation-minded anglers. It is available from the IGFA, for $7.95.

Marine Recreational Angling and Management

"Marine Recreational Fisheries 8," subtitled "Marine recreational fisheries at the crossroads" and edited by Richard H. Stroud, has been published by the Sport Fishing Institute for the International Game Fish Association, National Coalition for Marine Conservation, and the SFI. It presents the proceedings of the Eighth Annual Marine Recreational Fisheries Symposium held in San Diego, Calif., on 26-27 April 1983.

The symposium and its proceedings were divided into six panels: 1) A general audit of important MRF resources and habitats chaired by Charles Fullerton; 2) a profile of marine resource user groups and the recreational industry, and their relationship to each other and to conservation chaired by Stuart Wilk; 3) an assessment of the state of the art of fisheries science, management, and enforcement techniques, plus an identification of specific needs chaired by Herbert Kameon; 4) a review of the structure and operation of the various management institutions and their successes and failures chaired by Ted Naftzger, Jr.; 5) an examination of the management policies affecting various species chaired by Izadore Barrett; and 6) a look at the present and future of marine fisheries management chaired by Peter Fithian.

In Panel 1, Elizabeth Venrick assesses the marine recreational fisheries of the California Current and John Pearce gives a detailed look at problems facing marine fisheries habitats. J. Frank Cogdell, in Panel 2, relates the MRF industry's role in fisheries development, while Lee Weddig and Edwin Martin give perspectives on the common grounds of the commercial and recreational fisherman.

In Panel 3, Gary Stauffer discusses the tools and concepts of fishery stock assessments, while Richard Hennemuth examines the role of scientific information in MRF management. And, James Messersmith and John Baxter examine the role of enforcement in marine fisheries management. In the fourth panel, Carmen Blondin reviews international fisheries management institutions, John Gottschalk discusses interstate cooperation in marine fish management, and George Reiger suggests ways that private organizations could do more to improve fisheries management. In the final panel, Charles Lyles and Richard A. Klingbeil discuss various facets of recreational fisheries management and William Gordon outlines several complex issues (allocations, conservation, funding, and habitat quality) which impinge on the future of MRF. In addition, he suggests moving toward a "unifying theory of fisheries management designed to provide fair and equitable treatment to all fisheries resource users," and toward a "conservation ethic in the future centered around the principle of taking no more than is needed or can be used."

The book provides some excellent and timely reviews of issues important to the future of MRF. Indexed, the 236-page hardbound volume is available from the International Game Fish Association, 3000 East Las Olas Boulevard, Fort Lauderdale, FL 33316-1616 for $15.00.

Recreational Fishermen

"Understanding Involved Fishermen: A Survey of Members of the Gulf Coast Conservation Association," by Robert B. Ditton and Stephen M. Holland, has been published by the Sea Grant College Program, Texas A&M University, College Station, TX 77843 as TAMU-

SG-84-623. It is a study of members of an association (of about 10,000 members) concerned with fishery conservation issues and the protection of recreational fishing interests.

Respondents (392 of 559 randomly selected members) were mostly middle-aged male anglers in professional-technical occupations with $40,000+ annual family incomes. Virtually all were active anglers who fished an average of 37 days per year, seeking most often speckled trout (in which 67 percent specialized), redfish, flounder, largemouth bass, and king mackerel, in that order. The GCCA members exhibited a pattern of "enhanced involvement" in fishing via magazine readership, club membership, tournament participation, boat ownership, and higher self-reported skill and catch levels. A majority of respondents also would support a variety of fishery conservation options, even if it required self-sacrifice in lower catch or higher fees. The 70-page paperbound report is available from the publisher for $2.00.

Salmon and Salmon Fisheries of Alaska

"Alaska's Salmon Fisheries," edited by Jim Rearden, has been published by The Alaska Geographic Society as one of the quarterly issues of *Alaska Geographic*, 10(3):1-128. Lavishly illustrated with color photographs and charts of catch data, the issue covers each of the Pacific salmon caught in Alaska: Chinook, *Oncorhynchus tshawytscha*; coho, *O. kisutch*; pink, *O. gorbuscha*; sockeye, *O. nerka*; and chum, *O. keta*. Each species' biology, range, common names, and other characteristics, plus native and commercial utilization, and average weights by state region and the statewide salmon catch (1973-82) are given.

Another section reviews salmon fishing gear and how it is used. Seines take almost half of Alaska's commercial salmon harvest (depending on species) (85 percent of the pink salmon, but only 2 percent of the chinook and 15 percent of the sockeye). Gill nets (drift and set) take about 48 percent of all salmon. Fish wheels, take less than 1 percent of the salmon and troll gear takes about 2 percent.

The largest section reviews Alaska's salmon fisheries by fishing region—and there are 13 different salmon management areas: Southeastern, Prince William Sound, Cook Inlet, Kodiak, Chignik, South Peninsula and North Peninsula, Aleutians, Bristol Bay, Kuskokwim, Yukon, Norton Sound, and Kotzebue Sound. Climate, geology, and other data is given for each, along with the types of fishing, species harvested, and percentages of the total state catch, brief histories of the fisheries, and the current fishery status. The paperbound 128-page volume is available from the Society at Box 4-EEE, Anchorage, AK 99509-6057 for $12.95 ($15.50 in Canada). Other marine-related AGS publications include "Islands of the seals: The Pribilofs," 9(3), $9.95; "The Aleutians," 7(3), $14.95; and "Alaska whales and whaling," 5(4), $12.95. A revised edition of "Fisheries of the North Pacific" by Robert Browning is also available, hardbound, at $24.95.

Fisheries of Indonesia And Taiwan Are Reviewed

Indonesia

Indonesian fishermen caught 1.87 million metric tons (t) of fish and shellfish in 1981, just 1 percent over the 1980 catch of 1.84 million t. Small-scale, artisanal fishermen harvested about 90 percent of the catch. Curing is the most important form of fish processing and over 50 percent of the catch was salted or dried in 1981. Only a small portion of the catch was canned and the rest was frozen or marketed fresh.

Indonesia's 1981 exports totalled 85,000 t, valued at over US$230 million. Indonesia's fishery imports totalled 31,000 t in 1979 and, while more current data are not yet available, projections indicate that imports have decreased in recent years and many observers expect them to continue to decline. Opportunities for U.S. fishery-related exports to Indonesia are primarily for fishing vessels, freezing equipment, processing euipment, and fishing gear.

Tappan Banerjee, a National Marine Fisheries Service official assigned to the U.S. Embassy in Jakarta, has prepared a 77-page report on Indonesian fishery developments in 1981. The report contains information on catch, processing, trade, and consumption. The report also contains information on Indonesian companies, government officials, development plans, and foreign aid programs in Indonesia. U.S. companies can obtain a copy of the report for $5.00 by requesting ITA-83-02-009, "Indonesian Fisheries—A Status Report," from NTIS, Springfield, VA 22161.

Taiwan

Taiwan's 1982 fisheries catch totalled 922,383 t, also a 1 percent increase over the 1981 catch of 911,678 t. The value of the catch increased to US$1.44 billion, a 5 percent increase over the 1981 value of $1.37 billion. Taiwan's fishery exports amounted to $756 million in 1981 (latest available figure), a decline compared with fishery exports in 1978.

Taiwan's decrease in fishery exports is believed to have been caused by the worldwide economic recession and a Japan-China joint venture in Hongchow, China, which has begun to compete with Taiwanese fishery exporters for the Japanese market.

The American Institute in Taiwan has prepared a 15-page report on Taiwan's fishing industry in 1983, with 7 statistical tables, which presents a general outline of Taiwan's fisheries and chapters on Taiwan's fisheries catch, fleet, and trade. The report also contains a section describing opportunities for U.S. companies. U.S. firms can obtain a copy of this report for $7.00 by requesting PB 83-214650, "Taiwan's Fishing Industry," from NTIS, Springfield, VA 22161.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
BIN C15700
7600 SAND POINT WAY N.E.
SEATTLE, WA 98115

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210

Second Class

U.S.MAIL

MFR UNIVM300UFISSDUE006R 1 *
UNIV MICROFILMS INTL *
SERIALS PROCESSING 109 *
300 N ZEEB RD *
ANN ARBOR MI 48106 *